

Final Feasibility Study Work Plan Former Boeing-Tulalip Test Site Marysville, Washington

March 2, 2023

Prepared for


The Boeing Company
Seattle, Washington

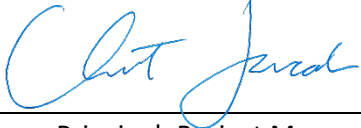


155 NE 100th St, Ste 302
Seattle, WA 98125
206.631.8680

Feasibility Study Work Plan Former Boeing-Tulalip Test Site Marysville, Washington

This document was prepared by, or under the direct supervision of, the technical professionals noted below.

Document prepared by:  Sarah Fees, LG
Associate; Primary Author

Document reviewed by:  Clint Jacob, PE, LG
Principal; Project Manager

Date: March 2, 2023
Project No.: 0025087.023.012
File path: P:\025\087\FileRm\R\FS WP 2022\Full FS WP_Revised\Landau Boeing Tulalip FS WP_Final 030223.docx
Project Coordinator: LJJ

This page intentionally left blank.

TABLE OF CONTENTS

	<u>Page</u>
1.0 INTRODUCTION	1-1
1.1 Objectives	1-1
1.2 Site Description	1-2
1.2.1 Setting and Site Definition	1-2
1.2.2 Site Operations and History	1-2
1.2.3 Geology and Hydrogeology	1-3
1.2.4 Site Condition and Use	1-4
1.2.4.1 Current Use	1-4
1.2.4.2 Future Use	1-5
1.3 Previous Investigations	1-6
1.3.1 Remedial Investigations	1-8
1.3.2 Interim Remedial Actions	1-8
1.3.3 Treatability Studies	1-8
1.3.3.1 Bioremediation Pilot Testing	1-9
1.3.3.2 Bioremediation Treatability Testing	1-10
1.3.3.3 ISCO Benchscale Testing	1-11
1.3.4 Human Health and Ecological Baseline Risk Assessment	1-11
1.4 Updated Conceptual Site Model	1-12
1.4.1 Conceptual Exposure Model	1-12
1.4.1.1 Incomplete or Insignificant Exposure Pathways	1-12
1.4.1.2 Potentially Complete Future Exposure Pathways	1-12
1.4.2 Areas of Concern and Hydrogeologic Conceptual Model	1-13
1.4.2.1 Area 1	1-15
1.4.2.2 Area 5	1-15
1.4.2.3 Area 8	1-16
1.4.2.4 Area 34	1-16
1.4.2.5 Area 41	1-17
1.4.2.6 Administration Area	1-18
2.0 IDENTIFICATION OF REMEDIAL ACTION OBJECTIVES	2-1
2.1 Remedial Action Objectives	2-1
2.2 Applicable or Relevant and Appropriate Requirements	2-1
2.3 Groundwater Preliminary Remediation Goals	2-1
2.4 Indoor Air PRGs and Action Levels	2-2
2.5 Screening During Redevelopment	2-3
3.0 IDENTIFICATION AND SCREENING OF REMEDIAL ACTION TECHNOLOGIES	3-1
4.0 PROPOSED REMEDIAL ALTERNATIVES	4-1
5.0 FEASIBILITY STUDY SCHEDULE AND OUTLINE	5-1
6.0 USE OF THIS REPORT	6-1
7.0 REFERENCES	7-1

FIGURES

<u>Figure</u>	<u>Title</u>
1	Vicinity Map
2	Former Boeing-Tulalip Test Site
3	cVOC Groundwater Plumes—Maximum Historical Extent
4	cVOC Groundwater Plumes—Current Extent (Most Recent as of July 2022)
5	Updated Conceptual Site Model
6	Area 1: TCE Groundwater Concentrations
7	Area 5: Combined Plume Extent
8	Area 8: VC Groundwater Concentrations
9	Area 34: Combined Plume Extent
10A	Area 41: TCE Groundwater Concentrations, West of I-5
10B	Area 41: TCE Groundwater Concentrations, East of I-5
11	Administration Area: TCE Groundwater Concentrations

TABLES

<u>Table</u>	<u>Title</u>
1	Test Areas Summary
2	Groundwater Plume Summary
3	Applicable or Relevant and Appropriate Requirements
4	Preliminary Remediation Goals—Groundwater
5	Action Levels and PRGs for Protection of Commercial Indoor Air
6A	Screening of Technologies and Process Options Applicable to Soil Vapor
6B	Screening of Technologies and Process Options Applicable to Groundwater
7	Retained Technologies by Area
8A	Proposed Alternatives—Category A Areas of Concern
8B	Proposed Alternatives—Category B Area of Concern
8C	Proposed Alternatives—Category C Area of Concern
8D	Proposed Alternatives—Category D Area of Concern

APPENDICES

<u>Appendix</u>	<u>Title</u>
A	EPA Approval Letter and Responses to Draft Report Comments from EPA and the Tribes

LIST OF ABBREVIATIONS AND ACRONYMS

µg/L.....	micrograms per liter
Admin.....	Administration
AOC.....	area of concern
ARAR.....	applicable or relevant and appropriate requirement
ASAOA.....	Administrative Settlement Agreement and Order on Consent
AST.....	aboveground storage tank
bgs.....	below ground surface
Boeing.....	The Boeing Company
BRA.....	baseline risk assessment
cDCE.....	cis-1,2-dichloroethene
CERCLA.....	Comprehensive Environmental Response, Compensation, and Liability Act
COC.....	chemicals of concern
CSM.....	conceptual site model
cVOC.....	chlorinated volatile organic compound
DGR.....	dynamic groundwater recirculation
DHC.....	<i>Dehalococcoides sp.</i>
DNAPL.....	dense non-aqueous phase liquid
Ecology.....	Washington State Department of Ecology
EISB.....	enhanced <i>in situ</i> bioremediation
EPA.....	US Environmental Protection Agency
ERA.....	ecological risk assessment
ESA.....	environmental site assessment
FS.....	feasibility study
FSWP.....	feasibility study work plan
ft.....	feet, foot
GMS.....	Groundwater Modeling System
GRA.....	general response action
HAZWOPER.....	Hazardous Waste Operations and Emergency Response
HHRA.....	human health risk assessment
HI.....	hazard index
I-5.....	US Interstate 5
IRA.....	interim remedial action
ISCO.....	<i>in situ</i> chemical oxidation
ISCR.....	<i>in situ</i> chemical reduction
Landau.....	Landau Associates, Inc.
LUST.....	leaking underground storage tank
MCL.....	maximum contaminant level

LIST OF ABBREVIATIONS AND ACRONYMS (CONTINUED)

MNA	monitored natural attenuation
NCP	National Contingency Plan
PRG	preliminary remediation goal
QAPP	quality assurance project plan
QCV	Quil Ceda Village
RAO	remedial action objective
RBSL	risk-based screening level
RCW	Revised Code of Washington
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
ROD	Record of Decision
ROW	right of way
Site	former Boeing-Tulalip Test Site
SOW	statement of work
TCE	trichloroethene
Tribes	Tulalip Tribes
UST	underground storage tank
VC	vinyl chloride
WAC	Washington Administrative Code
WFQC	West Fork Quilceda Creek
yd ³	cubic yards

1.0 INTRODUCTION

This document presents a feasibility study work plan (FSWP) for the former Boeing-Tulalip Test Site (Site). The purpose of this FSWP is to describe the procedures for performing the feasibility study (FS) for the Site. This FSWP is being conducted as part of the requirements specified in the Administrative Settlement Agreement and Order on Consent (ASAOC), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Docket No. 10 2010 0245 between the US Environmental Protection Agency (EPA) and The Boeing Company (Boeing; EPA 2010). This FSWP has been revised based on comments received from the EPA and the Tulalip Tribes (Tribes). Comments and responses are presented in Appendix A.

Implementation of the FS follows completion of the remedial investigation (RI) including the baseline risk assessment (BRA). The RI was complete upon EPA's approval of the BRA Report on July 19, 2022 (Landau Associates, Inc. [Landau] and Pioneer 2022). Documentation of the completed RI consists of Final Remedial Investigation and Summary of Existing Information Report (RI Summary Report; Landau 2017b), RI Data Gaps Investigation Report (Landau 2020), and the Final BRA Report (Landau and Pioneer 2022).

The FSWP uses the information obtained from the RI/BRA including the results of treatability testing conducted at the Site to evaluate potential treatment technologies for human health and ecological chemicals of concern (COCs). Various information points from the RI are summarized in this FSWP, and the reader is referred to the RI documents for further detail.

The FS will be performed in general accordance with EPA Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA 1988), Guidance for Data Usability in Risk Assessment (Part A) (EPA 1992a), and this FSWP. The FS will use data and conclusions from the RI/BRA, the results of treatability testing conducted at the Site, and groundwater monitoring well data through 2022 to evaluate potential treatment technologies for COCs. The BRA concluded that three COCs consisting of chlorinated volatile organic compounds (cVOCs) require further evaluation in the FS: trichloroethene (TCE) and its breakdown products cis-1,2-dichloroethene (cDCE) and vinyl chloride (VC).

1.1 Objectives

The objectives of this FSWP are:

- Develop remedial action objectives (RAOs).
- Define applicable or relevant and appropriate requirements (ARARs).
- Present proposed preliminary remediation goals (PRGs). Action levels for groundwater and soil vapor which are protective of indoor air are also presented.
- Present screening of cleanup technologies resulting in a list of retained technologies that will be further evaluated in the FS.

- Compile and present the remedial alternative to be evaluated in the FS.
- Present an outline of the FS report and methods to be used for cleanup alternative analysis in the FS.

1.2 Site Description

The Site is located near Marysville, Washington and falls within the Tulalip Indian Reservation and contiguous properties to the east. The Site location is shown on Figure 1. The Site is made up of 16 individual test areas based on former site operations. The test areas are summarized in Table 1 and shown on Figure 2. All test sites were evaluated in the completed RI and BRA. The maximum and current extents of the six COC groundwater plumes are shown on Figures 3 and 4, respectively. This section describes the extent of the Site, summarizes geology and hydrogeology, describes Site operations and history, and describes Site use including current uses and likely future uses.

1.2.1 Setting and Site Definition

The Site was defined in the ASAO as the Boeing-Tulalip Test Site Superfund site (former Boeing-leased property located on the Tulalip Indian Reservation) and adjacent property where hazardous substances at or from the Boeing-leased property have come to be located (EPA 2010). The Site was redefined in the Data Gaps Investigation Report to include a newly characterized TCE groundwater plume extending off the reservation from Area 41 beneath an undeveloped residential parcel (Landau 2020). The revised Site, totaling approximately 600 acres, includes portions of three parcels formerly leased by Boeing from the Tribes and two contiguous areas extending east of US Interstate 5 (I-5) from the Area 41 and the Administration (Admin) Area. I-5 is located along the eastern boundary of the reservation. The three parcels of the former Boeing leasehold totaled approximately 1,376 acres. Parcel 1, the Main Test Area (9730 19th Avenue), was 1,270 acres and constituted the majority of the Site; Parcel 2, the Admin Area (11224 34th Avenue NE), was 20.7 acres; and Parcel 3 was 85.3 acres. The Site and former Boeing leasehold parcels are shown on Figure 2.

The Site is relatively flat, sloping gently to the east and south. Several roads cross the Site and most of the former test areas are located adjacent to these roads. Revetment Road, near the western edge of the developed portion of the Site, is at the foot of a north-south trending ridge. The Site is bounded to the south and east by tributaries of Quilceda Creek, which control the flow of groundwater and surface water at the Site. The West Fork Quilceda Creek (WFQC) is located east of the Site and I-5. Coho Creek crosses the Site from north to south along West Security Road fed by various Site tributaries, including roadside ditches. Coho Creek flows east along the south boundary of the Site and continues to the southeast. Sturgeon Creek is located to the south of the Site. Site features and creek locations are shown on Figure 2.

1.2.2 Site Operations and History

The US Department of Defense acquired the Site property by imminent domain for ammunition storage and training purposes during World War II. In 1948, the Site was re-acquired by the Tribes

through purchase from a Federal Government surplus land sale. The Site was then leased to the US Government in the 1950s. Boeing leased portions of the Site beginning from about 1960 through June 2001. Boeing activities varied and included missile, jet engine, and small rocket testing performed at more than a dozen discrete test areas located on Parcel 1. Support activities typically took place in the Admin Area on Parcel 2. Parcel 3 activities consisted of two test areas and a helipad.

1.2.3 Geology and Hydrogeology

The Site is located in the Marysville Trough and underlain by recessional outwash sand deposits from the Vashon Stade of the Fraser Glaciation deposits extending to at least 100 feet (ft) below ground surface (bgs). Deposits are locally characterized as a relatively homogenous sequence of poorly graded fine to medium sand with varying amounts of silt, coarse sand, and gravel. Underneath the Marysville Trough are transitional Olympia interglacial clay, silt, and sand deposits with discontinuous layers of sand and gravel, and along the western valley margin, glacial till, and outwash deposits. Transitional sediments begin at approximately 100 ft bgs in the Marysville Trough (Washington State Department of Ecology [Ecology] 2015). However, RI borings have not encountered the base of the Marysville Trough except in the western margin of the Site where the aquifer thins against a north-south trending ridge of glacial till.

The shallow, unconfined aquifer beneath the Site consists of the saturated recessional outwash sands extending to at least 100 ft bgs. Groundwater depth ranges from less than 1 ft bgs in the winter in the central portion of the Site (Area 34) to more than 27 ft bgs in the summer near the east portion of the Site (Admin Area). The average linear groundwater flow rate is estimated to be from 0.5 to 1.5 ft per day at the Site.

Groundwater flow is generally southeast to east toward Quilceda Creek and its tributaries. Recharge of the shallow aquifer is primarily from infiltration of precipitation, with some recharge from adjacent and underlying water-bearing zones and from surface water. Shallow groundwater flow from the western margin of the trough is a source of local recharge. Groundwater flows toward zones of discharge along Quilceda Creek and its tributaries. Flow becomes more easterly near Coho Creek and the WFQC.

Groundwater geochemistry varies from aerobic to anaerobic at the Site and is important in understanding contaminant fate and transport processes. Natural attenuation of TCE and breakdown products through biotic (i.e., biological) and abiotic processes typically occurs under anaerobic aquifer conditions. The most common biodegradation process is reductive dechlorination, whereby bacteria sequentially reduce TCE to breakdown products cDCE and VC, and finally to non-toxic end products ethene and/or ethane. TCE is a relatively oxidized compound that can be reductively dechlorinated to cDCE under mildly reducing conditions (iron-reducing conditions). However, highly reduced redox conditions (i.e., methanogenic conditions) are required for complete reductive dechlorination through VC to ethene and ethane. Area-specific redox conditions are described further in Section 1.4.2.

TCE and breakdown products are retarded differently relative to groundwater flow due to chemical characteristics and various plume attenuation factors including biological degradation; chemical (abiotic) degradation; and physical processes including dispersion, dilution, sorption, and volatilization. Based on solid organic carbon data collected during Site explorations, the Site-specific retardation factor for TCE is about 2.5 (i.e., dissolved TCE is expected to travel at an average velocity approximately 1/2.5 or 40 percent that of groundwater). Due to a lower affinity for sorption to organic carbon, the breakdown products cDCE and VC will be less retarded than TCE (i.e., will travel more quickly and further).

1.2.4 Site Condition and Use

The Site is relatively flat and approximately two-thirds covered by second growth forest and forested wetlands, while about one-third of the Site was previously developed. Prior development consists of individual areas used historically by the US Government for ammunition storage during World War II and areas used by Boeing for testing and administration. US Government igloos and nearly all Boeing buildings have been demolished. Former Boeing buildings in the Admin Area, Area 5, and Area 14 remain and continue to be utilized by the Tribes. Surrounding land uses beyond the Site are residential, commercial, and light industrial.

1.2.4.1 Current Use

The Site is owned and operated by the Tribes except for the I-5 right of way (ROW; easement at the east edge of the reservation) and at the east end of the Area 41 groundwater plume, where the plume extends beneath an undeveloped residential parcel (the (b) (6) parcel No. 30051600203800). The distal end of the Admin Area plume between I-5 and the WFQC occurs on a formerly private parcel that was purchased by the Tribes in the early 2000s.

All of the Site west of I-5 is within the Tribes' Quil Ceda Village (QCV), which is owned by the Tribes and held in Tribal trust. The Consolidated Borough of QCV is incorporated as a Federal City under a municipal government charter, with a Village council and Village manager, pursuant to the limitations imposed by the constitution and laws of the Tribes as the property's landowner. Neither the Village Council, nor the Tribes' Board of Directors, plan to use QCV for residential development. The QCV is zoned for commercial and light industrial, with uses that might include retail, service-oriented commercial, office, manufacturing, warehousing, light industrial, and storage (Tulalip Tribes 2009). West of I-5, there are commercial buildings located over or near the Admin and Area 41 plumes.¹ The Tribes operate a plant nursery in Area 5 and maintain the former Boeing building in Area 14. Tribal police utilize portions of Area 1 and Area 4 as shooting ranges.

¹ Indoor air risk was evaluated for these buildings in the BRA and shown not to be a concern.

The largest (western) portion of the Site is undeveloped and may be used by Tribal members for harvesting of various materials (e.g., basket materials) and foodstuffs (e.g., fish and native plants). Tribal harvester risk was evaluated in the BRA and shown not to be a concern.

Access is restricted to portions of the Site. The main (western) portion of the Site is surrounded by a 9-ft-tall chain-link fence and accessed via a keypad-controlled gate located in the northeast corner of the Site from 27th Avenue; however, the fence has been breached at various points by fallen trees allowing unrestricted access. The Admin Area is also fenced and gated. The southeast portion of the Site (Area 41) is located between the Seattle Premium Outlet Mall stores and Tulalip Casino and is open to the public.

Groundwater is not used for drinking water at the Site. A Beneficial Water Use Survey performed in 2000 and updated in 2020 (Landau 2000, 2020) compiled information on water supply wells near the Site. No water supply wells are located within the Site nor within areas that are hydraulically downgradient of the contaminant plumes. Surface water at the Site is not a source of drinking water per Washington State Law (Revised Code of Washington [RCW], Chapters 90.22 and 90.54 as outlined in Washington Administrative Code [WAC] Chapter 173 507), which states that Quilceda Creek is closed to further consumptive appropriation and has been closed since 1946 (WAC 173 507 030[2]). The WFQC and Coho Creek, located on the Site, are tributaries to Quilceda Creek. The Site, and many businesses and residences in the vicinity of the Site, are currently on a municipal water supply provided by the Tribes or the City of Marysville and City of Everett.

1.2.4.2 Future Use

Future Tribal land Site use will be commercial and/or light industrial based on QCV zoning. Uses may include retail, service-oriented commercial, office, manufacturing, warehousing, light industrial, and storage (Tulalip Tribes 2009). The Village Council and the Tribes' Board of Directors determine land use within QCV and residential development is not allowed. Screening of soil and groundwater that may be encountered during future development activities is described in Section 2.5.

As described in the Comprehensive Land Use Plan for the Tulalip Reservation (Tulalip Tribes 2009), the Tribes are intentional about acquiring municipal water supply from off-Reservation to "...significantly reduce on-Reservation aquifer groundwater withdrawals" in order to "...have a positive effect on area stream flows and area groundwater supplies". The plan notes that "Further withdrawals could negatively impact the Reservation surface water by lowering the flow during critical salmon rearing that will impair natural propagation and hatchery salmon production." To eliminate the need for future additional use of on-Reservation groundwater as drinking water, the Tribes have an agreement with the City of Everett to provide 30 to 35 million gallons per day. Infrastructure related to the City of Everett supply include a 48-inch pipeline and a new 1-million-gallon reservoir at QCV. Although unlikely, the BRA evaluated exposure to commercial workers through possible future use of shallow Site groundwater as drinking water. PRGs (see Section 2.3) presented in this FSWP are also based on the unlikely future use of shallow Site groundwater as drinking water.

The (b) (6) parcel is zoned for residential development (Single Family Medium R-4.5) but is currently undeveloped. Potential future residential development on this parcel is likely restricted to approximately 7 acres of upland area of the 18.5-acre parcel due to critical area designation. Installation of a future residential drinking water well would not be allowed based on State of Washington and City of Marysville requirements that future development on the (b) (6) parcel utilize City water.

1.3 Previous Investigations

RI activities began at the Site in 1987 and continued through July 2022 when EPA approved the BRA Report, which completed the RI phase of the project. Parcel 3 environmental site assessment (ESA) was conducted in 1987 through 1992 prior to termination of Boeing's lease (Boeing 1992). An ESA for Parcels 1 and 2 was conducted in 1997 and 1998 (Golder 1998), which was used to develop the initial RI scope of work, followed by phased investigations, interim remedial actions (IRAs), data gaps investigations, and groundwater monitoring. Four primary phases of RI activities and associated IRAs were performed from 1998 through 2001. With the exception of buildings retained by the Tribes, Boeing buildings were demolished during late 1998 through early 1999. Pilot testing and treatability testing for cVOCs in groundwater occurred between 2000 and 2019. Additional data gaps investigations occurred in 2008 to 2009 and 2017 to 2019. A BRA was completed for the Site between 2016 and 2022. The chronology of investigations and IRAs are summarized in the table below; these activities are documented in the in the three documents that together comprise the RI report: RI Summary Report (Landau 2017b), Data Gaps Report (Landau 2020), and BRA Report (Landau and Pioneer 2022).

Investigation Phase	Activity	Time Period	Test Areas Investigated
Pre-Remedial Investigation	Parcel 3 ESA (Boeing 1992)	1987–1992	Area 2, Area 41, helipad
	Parcel 1 and 2 ESA (Golder 1998)	1997–1998	Area 1, Area 4, Area 5, Area 7, Area 8, Area 9, Area 14, Area 31, Area 34, Area 43, Admin Area, misc. areas (Bldg. 16-417, Bldg 16-420, Bldg 16-423, Igloo 26)
Remedial Investigation Activities	Phase I Investigation	1998–1999	Area 1, Area 4, Area 5, Area 9, Area 14, Area 31, Area 34, Area 43, Former Burn Area, Admin Area, Bldg 16-420, Bldg 16-423
	Phase II Investigation	1999	Area 1, Area 4, Area 5, Area 8, Area 9, Area 14, Area 29, Area 34, Area 43, Former Burn Area, Admin Area, Bldg 16-420, Igloo 26
	Phase III Investigation	1999–2000	Area 1, Area 5, Area 1, Area 34, Former Burn Area, Admin Area
	Phase IV and Follow-up	2000–2004	Admin Area
	Beneficial Land and Water Use Survey (Landau 2000, 2020)	2000 and 2020 update	Site-wide

Investigation Phase	Activity	Time Period	Test Areas Investigated
	Admin Area and Area 1 Data Gaps Investigation	2007–2008	Area 1 and Admin Area
	Site-wide Data Gaps Investigation	2017–2019	Area 1, Area 5, Area 8, Area 14, Area 29, Area 34, Area 41, Area 43, Admin Area, Building 16-420, Site-wide Road Base
	Supplemental Investigation for the BRA	2021–2022	Site-wide soils - antimony Groundwater in Admin Area - bis(2-ethylhexyl)phthalate Sub-slab vapor and indoor air samples from Admin Area Bldg 16-383
Remedial Investigation Reporting	RI Summary Report (Landau 2017b)	1998–2017	Site-wide
	RI Data Gaps Report (Landau 2020)	2017–2020	Site-wide
	BRA Report (Landau and Pioneer 2022)	2020–2022	Site-wide
Interim Remedial Actions and Treatability Studies	Soil and Debris Removal, Fuel pipelines removed, Septic Tank Cleaning, Underground Storage Tank (UST) and Septic Tank Removal	1998–2001	Site-wide
	Numerical Groundwater Flow and Contaminant Transport Model (Landau 2001)	2001	Site-wide
	Pilot Testing for Bioremediation of TCE in Groundwater (Landau 2011, 2021c)	2000–2011	Area 5, Area 34
	Bench Testing for <i>In Situ</i> Chemical Oxidation (ISCO) of TCE in Groundwater	2001	Area 34 and Admin Area
	Vapor Intrusion Modeling	2003	Admin Area
	Leaking UST (LUST) Facility Closure	2004	Area 14
	Admin Area Additional Source Removal Interim Action	2009	Admin Area
	Area 34 Bioremediation Treatability Testing (Landau 2021c)	2010–2019	Area 34
Ongoing Activities	Ongoing Groundwater Monitoring	2000–Present	Site-wide
	EPA Quarterly Reports	2010–Present	Site-wide

1.3.1 Remedial Investigations

RI data was collected from 16 individual test areas throughout the Site.² A summary of Site use, interim actions, and investigations is provided for individual test areas in Table 1. Test areas are located as shown on Figure 2.

RI analytical data consists of soil, groundwater, surface water, soil vapor, and indoor air data. The RI Summary Report (Landau 2017b) documented RI data and findings, and associated IRAs through March 2015. The RI Summary Report also presented a screening level BRA in accordance with the ASAO that consisted of 1) rescreening of Site data against risk-based screening levels (RBSLs), and 2) the BRA Work Plan.³ The RI Data Gaps Report (Landau 2020) presented additional RI data from March 2015 through November 2019 and an updated nature and extent of contamination and conceptual site model (CSM). The BRA evaluation followed the Data Gaps Report and was finalized in 2022; the BRA is described further in Section 1.3.4. Documentation of the completed RI consists of the RI Summary Report (Landau 2017b), RI Data Gaps Investigation Report (Landau 2020), and the BRA Report (Landau and Pioneer 2022).

The BRA concluded that the COCs requiring further evaluation in the FS are TCE and its breakdown products cDCE and VC. The BRA identified these compounds as risk drivers in five Site groundwater plumes (Admin Area, Area 1, Area 4, Area 34, and Area 41). Although not shown to have unacceptable risk in the BRA, Area 8 is also included in the FS due to VC concentrations above the PRGs (Section 2.3).

1.3.2 Interim Remedial Actions

IRAs occurred at many of the individual areas of the Site beginning in 1998. The IRAs for each test area are described in Table 1. IRAs included pumping and cleaning of septic tank systems (12), removal of septic tanks (four), underground storage tank (UST) removal (one), draining and removal of jet fuel pipelines (1,200 ft), and excavation/disposal of impacted soil and debris (5,300 cubic yards [yd³]). Prior to 1998, additional USTs and aboveground storage tanks (ASTs) were removed by Boeing from various areas, including Area 9, Area 14, Area 34, and the Admin Area, with further investigation of these areas completed during the RI.

1.3.3 Treatability Studies

Treatability testing consisted of bioremediation pilot testing, bioremediation treatability testing, and *in situ* chemical oxidation (ISCO) bench testing. Bioremediation pilot testing occurred in Area 5 and Area 34 from 2000 to 2010. Bioremediation treatability testing was conducted in Area 34 to evaluate

² Area 1, Area 4, Area 5, Area 8, Area 9, Area 14, Area 29, Area 31, Area 34, Area 41, Area 43, Former Burn Area, Admin Area, Igloo 26, Building 16-420, and Building 16-423. Soil samples were also collected from Site roads as part of the RI data gaps investigation.

³ Subsequently expanded on by four work plan addenda (Landau 2021a, Landau 2021b, Landau and DHEC 2020a, Landau and DHEC 2020b).

the effectiveness to treat the entire plume from 2011 through 2019. ISCO bench testing for oxidant demand was performed on soils from Area 34 and the Admin Area in 2001.

In 2001, a numerical groundwater flow and contaminant transport model was also developed for the west-central portion of the Marysville Trough Aquifer. The model was developed using Version 3.0 of the Groundwater Modeling System (GMS) as the model platform. Other groundwater flow programs were used with GMS as follows:

- MODFLOW was used to simulate hydraulic heads over the model area.
- MODPATH was used to simulate flow paths using particle tracking.
- RT3D was used to simulate reactive contaminant transport in groundwater.

The model was intended to support evaluation of groundwater pump-and-treat using a hypothetical pumping well located in the Admin Area. However, the rate of plume restoration predicted by the model was more rapid than observed in actual data. Attempts to calibrate the model results to actual TCE groundwater concentration data over time were unsuccessful and further numerical modeling was suspended.

Simpler batch flush modeling is planned during the FS to support evaluation of dynamic groundwater recirculation (DGR).

1.3.3.1 Bioremediation Pilot Testing

In situ bioremediation pilot testing began at the Site in 2000 and continued until March 2008, when injection activities were suspended by the EPA until the ASAO was finalized (EPA 2010). Area 34 pilot testing was resumed with a final injection event in December 2010 and concluded with the final sampling event in January 2011. Area 34 was the smallest Site plume and had the highest TCE concentrations. Pilot testing was primarily conducted in the middle and downgradient portions of the Area 34 TCE plume, resulting in continual contaminant flux into the pilot test area from the upgradient portion of the plume. Pilot testing was also performed to a lesser degree in Area 5 from 2004 to 2006 to confirm Area 34 results (Landau 2017b). Pilot test results are documented in the RI Report (Landau 2017b) and in the final Area 34 pilot test report (Landau 2011). Lessons learned and design parameters from the pilot testing are summarized as follows:

- The combination of soluble sodium lactate (fast-release donor) and insoluble vegetable oil (slow-release donor) was determined to be the most effective electron donor substrate tested.
- Bioaugmentation by injection of non-native bacterial inoculum containing the Bachman Road strain of *Dehalococcoides sp.* (DHC) was found to be a critical step to achieving complete dechlorination of TCE through cDCE and VC to non-toxic end products.
- Complete reductive dechlorination of TCE through breakdown products cDCE and VC to non-toxic end products ethene and ethane was demonstrated. Ethene+ethane had become the predominant ethene on a molar basis (i.e., more of the non-toxic end product present than TCE, cDCE, or VC) at six monitoring wells as of the final pilot test sampling event.

- Pilot and tracer test results indicated that individual injection wells and rows of injection wells could be spaced farther apart than anticipated prior to pilot testing while still providing treatment of planned plume sections. Based on pilot test results, the treatability test utilized injection well spacing of 15 ft apart and up to 150 ft between injection rows.

1.3.3.2 Bioremediation Treatability Testing

Treatability testing was performed as a next step to evaluate treatment of the entire Area 34 plume. The treatability test objective was to achieve treatment of TCE, cDCE, and VC to maximum contaminant levels (MCLs),⁴ defined as target treatment levels, throughout the groundwater plume. Between 2011 and 2017, five rounds of donor injections, including two bioaugmentation events, were conducted in the Area 34 plume.⁵ Treatability testing results are documented in the Area 34 bioremediation treatability testing completion report (Landau 2021c). Lessons learned for future treatment activities are summarized as follows:

- Future injections should avoid the wet season in plumes with shallow groundwater, where feasible.
- A longer interval (more than 5 months) between injections may be acceptable and will be considered for future injections to the other plumes.
- Treatability tests conducted throughout the Area 34 target treatment zone confirmed that bioremediation consisting of biostimulation with electron donor substrates and DHC bioaugmentation, successfully treated TCE, cDCE, and VC through to non-toxic end products ethene and ethane. TCE concentrations were reduced below the MCL at all wells and cDCE was above the MCL at only one well.
- VC remained above the MCL at just more than half of the wells (16 of 27) at the end of the treatability test. However, the maximum VC concentration in the final sampling event was just 12 percent of the peak concentration during treatability testing. Despite remaining VC, the BRA Report (Landau and Pioneer 2022), showed substantial reduction in cancer and noncancer risk to within or below the EPA acceptable risk range due to biodegradation of TCE and breakdown products resulting from the Area 34 treatability test. VC concentrations are expected to further decrease over time through natural attenuation.
- Treatment enhancements that can be considered for lower VC production or persistence during future application of bioremediation to other plumes at the Site include:
 - The addition of ferrous sulfate to injection fluid to stimulate complementary abiotic degradation of TCE and cDCE without the formation of VC.
 - pH buffering and continued use of low pH acclimatized bioaugmentation culture to mitigate the observed low-pH cDCE-stall at and near injection wells.
 - Tighter spacing between injection rows than utilized during treatability testing (i.e., less than 150 ft). Tighter spacing could allow a lower dosing of donor, reducing the low-pH impacts. Tighter spacing may also improve donor distribution and contact with

⁴ The MCLs are 5 micrograms per liter (µg/L; TCE), 70 µg/L (cDCE), and 2 µg/L (VC).

⁵ The first three donor injection events and first bioaugmentation targeted the entire plume, while the last two donor injection events and final bioaugmentation were focused on the northern rows.

residual contaminants, reducing the period of matrix back diffusion and the required period of monitored natural attenuation (MNA).

1.3.3.3 ISCO Benchscale Testing

Site-specific ISCO benchscale testing was performed using soil from Area 34 (anaerobic aquifer) and the Admin Area (aerobic aquifer) as a screening evaluation of ISCO use at the Site. Aquifers with abundant natural organic carbon are anaerobic and have high natural oxidant demand that can prevent successful implementation of ISCO. Testing concluded that the oxidant demand of tested Site soil was not excessive for use of ISCO at the Site. Although not excessive, the oxidant demand of samples from Area 34 was approximately twice that of the oxidant demand for the Admin Area sample, consistent with the anaerobic aquifer conditions in Area 34. Results for Area 34 are considered representative of Area 5 and Area 8, which are similarly anaerobic, while results for the Admin Area are considered representative of the other aerobic plumes in Area 1 and Area 41.

1.3.4 Human Health and Ecological Baseline Risk Assessment

The BRA finalized in 2022 included both a human health risk assessment (HHRA) and an ecological risk assessment (ERA). The purpose of the BRA is to evaluate potential adverse health impacts to human health and ecological receptors exposed to constituents in air, soil, groundwater, shallow/ponded water, and surface water at the Site. The HHRA evaluated potential human health receptors for child and adult tribal harvesters, adult commercial workers, and adult construction workers. The ERA evaluated the potential adverse effects to terrestrial plants, soil invertebrates, voles, shrews, and robins for individual test areas of the Site; potential effects to fish were also evaluated where groundwater plumes discharge to the WFQC and Coho Creek. Results of the BRA (Landau and Pioneer 2022) are summarized below and used to update the Site CSM as described in Section 1.4:

- No unacceptable risk was identified for the tribal harvester. The incremental cancer risks calculated for the child and adult tribal harvester were within the EPA's acceptable risk range of 1E-04 to 1E-06. The incremental noncancer hazard index (HI) calculated for the child and adult tribal harvester were below the EPA benchmark of 1.
- The COCs driving risk and requiring further evaluation in the FS are TCE and its breakdown products cDCE and VC. The BRA identified these compounds as risk drivers in five site groundwater plumes (Admin, Area 1, Area 5, Area 34, and Area 41). Vapor intrusion institutional and engineering control requirements related to these COCs also require evaluation in the FS.
 - The incremental cancer risks for the adult construction worker exceeded EPA's acceptable risk range of 1E-04 to 1E-06 only at Area 34. However, these risks for Area 34 were based on the conservative BRA data set, which included one-time groundwater samples collected prior to pilot testing and treatability testing (including maximum TCE concentrations), as well as most recent groundwater data near the end of the treatability test (including VC concentrations created during treatability testing). As noted above, the BRA treatability testing in Area 34 resulted in a substantial reduction in area-specific risk, based on data collected in 2019; using this

2019 data only, the BRA showed that all cancer and noncancer risk for Area 34 was within or below the EPA acceptable range following the treatability test.

- The incremental noncancer HIs for the adult commercial worker were above the EPA benchmark of 1 in five TCE plume areas at the Site (Admin, Area 1, Area 5, Area 34, and Area 41 [west of I-5]).
- No unacceptable risk was identified for ecological receptors. It was concluded that a small number of ecological receptors may be impacted in individual test areas, but the larger community/population of those receptors at the Site are not adversely impacted.

1.4 Updated Conceptual Site Model

The CSM is comprised of the conceptual exposure model and the hydrogeologic conceptual model. The updated CSM based on the conclusions of the BRA (Section 1.3.4) is summarized in Figure 5.

1.4.1 Conceptual Exposure Model

Based on the conclusions of the BRA (Landau and Pioneer 2022), there are no current unacceptable Site exposure risks. Current exposure pathways are incomplete or insignificant, indicating no unacceptable exposure risks due to current Site use. Future Site development could result in complete future exposure pathways potentially with unacceptable risk. A summary of incomplete or insignificant exposure pathways and potentially complete future exposure pathways for Site COCs (TCE, cDCE, and VC in groundwater) are described below.

1.4.1.1 Incomplete or Insignificant Exposure Pathways

Incomplete or insignificant exposure pathways at the Site include:

- Current and future tribal harvester exposure
- Current commercial worker exposure
- Current construction worker exposure (no current construction is occurring over the groundwater plumes at the time of this report)
- Current and future ecological receptors exposure
- Future residential exposure (pertains only to the undeveloped residential parcel at the distal end of the Area 41 plume).

1.4.1.2 Potentially Complete Future Exposure Pathways

Potentially complete future risk pathways were identified for the Site in the BRA for future Site uses. Potentially complete future exposure pathways include:

- **Future construction worker** exposure to groundwater through excavation work over the TCE plumes. The BRA evaluation showed unacceptable risk to the construction worker in Area 34 only, using the highly conservative BRA data set that included TCE concentrations from before the treatability test and VC concentrations generated during the treatability test. However, as noted above, there was a substantial risk reduction in Area 34 at the conclusion of the

treatability test with all risk within or below the EPA acceptable risk range. Future bioremediation cleanup in other TCE plumes will also generate VC; therefore, this is identified as a potential future risk in the interim period while treatment is ongoing where bioremediation is selected as the future remedy.

Although the BRA showed no unacceptable risk to construction workers under current conditions in any of the areas, the precautions and procedures typical for contaminated sites are warranted in plume areas until cleanup is completed. This includes use of 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER)-trained crews for construction in plume areas and the development and use of media management plans governing soil and groundwater management during construction.

- **Future commercial worker** exposure to groundwater through the unlikely use of Site groundwater as drinking water. All drinking water within QCV is provided by municipal supply. As described in the Comprehensive Land Use Plan for the Tulalip Reservation (Tulalip Tribes 2009), the Tribes are intentional about acquiring municipal water supply from off-Reservation to “...significantly reduce on-Reservation aquifer groundwater withdrawals” in order to “...have a positive effect on area stream flows and area groundwater supplies.” The plan notes that, “Further withdrawals could negatively impact the Reservation surface water by lowering the flow during critical salmon rearing that will impair natural propagation and hatchery salmon production.” To eliminate the need for future additional use of on-Reservation groundwater as drinking water, the Tribes have an agreement with the City of Everett to provide 30 to 35 million gallons per day. Infrastructure related to the City of Everett supply include a 48-inch pipeline and a new 1-million-gallon reservoir at QCV. Although unlikely, the BRA evaluated exposure to commercial workers through possible future use of shallow Site groundwater as drinking water. PRGs presented in this FSWP are also based on the unlikely future use of shallow Site groundwater as drinking water.
- **Future commercial worker exposure** to vapor intrusion in buildings that could be built over the TCE plumes. Boeing will coordinate with the Tribes during construction planning for future habitable buildings constructed over groundwater plumes of TCE and breakdown products; engineering controls will be developed on a case-by-case basis (e.g., vapor barriers, crawl space ventilation) where risk to indoor air is indicated.

1.4.2 Areas of Concern and Hydrogeologic Conceptual Model

Six groundwater plumes containing the site COCs are identified as areas of concern (AOCs; Area 1, Area 5, Area 8, Area 34, Area 41, and Admin Area) to be evaluated in the FS.⁶ A summary of the sources and characteristics of the six groundwater plumes is provided in Table 2. The maximum extents and current extents of the six groundwater plumes are shown on Figures 3 and 4, respectively. A general overview of plume characteristics is as follows:

- The plumes consist of TCE and breakdown products within the unconfined, glacial outwash (recessional), sand aquifer of the Marysville Trough.

⁶ Although the BRA indicated that lower levels of VC present in groundwater in Area 8 do not result in unacceptable risk, Area 8 is included in the FS due to VC concentrations above the PRGs (Section 2.3). Similarly, Area 34 is included in the FS due to VC concentrations above the PRGs, although 2019 data at the end of the treatability test indicated no unacceptable risk.

- The plumes extend hydraulically downgradient from release areas, due to groundwater flow toward Quilceda Creek and its tributaries (e.g., WFQC and Coho Creek), plumes trend to the east or southeast.
- Three of the Site plumes discharge completely or partially to surface water. The Area 41 and Admin Area plumes discharge completely to the WFQC which forms the downgradient plume boundary. The Area 5 plume passes beneath Coho Creek, with the upper portion of the plume discharging to the creek during winter months when groundwater levels are higher. TCE and breakdown products were not detected in creek surface water samples collected in these areas in 2017 and 2019, with the exception of a single TCE detection at the laboratory reporting limit and well below the RBSL.⁷
- The plumes are stable or shrinking based on evaluation of monitoring data as described in the following sections.
- The highest concentrations of TCE in groundwater occur significantly downgradient from suspected release areas. This concentration distribution indicates that plumes are the result of historical aqueous-phase releases (i.e., not dense non-aqueous phase liquid [DNAPL] releases), with the highest concentrations having migrated downgradient over time as a slug of aqueous-phase contamination. This is in contrast to a DNAPL release, which would result in a persistent source in the release area having higher concentrations than those detected in the downgradient plume.
- Specific primary sources of the TCE plumes are known in some areas (septic systems—Area 34 and Admin Area, industrial drain field—Admin Area), but not in others. Released TCE may have been new or used solvent or other TCE-containing product. Source control measures have been taken to address primary sources (e.g., tanks) and secondary sources (e.g., soil contamination resulting from a release). These source control measures have been performed as IRAs as described in preceding sections. Known primary and secondary sources have been removed.
- There are no primary sources of cDCE or VC. Where present, these compounds are the results of TCE biodegradation within the aquifer (either naturally occurring or induced through injection of electron donor substrates to stimulated bioremediation).
- Three of the six plumes (Area 5, Area 8, and Area 34) are naturally anaerobic and substantial breakdown to cDCE occurs naturally, consistent with iron-reducing redox conditions. Further degradation to VC has occurred in Area 8 where VC is the predominant COC. Degradation through VC to detected concentrations of non-toxic end products ethene and ethane has only occurred in Area 5 and Area 34 due to bioremediation pilot testing and treatability testing. Three of the six plumes (Area 1, Area 41, and Admin Area) are aerobic and composed of TCE only; with a very localized exception in the Admin area where cDCE and VC are detected infrequently near the WFQC. Area 1 and Area 41 have only low levels of cDCE, consistent with an aerobic redox condition and minor cDCE production occurring in siltier layers/lenses which are anaerobic.

⁷ All samples were non-detect for TCE, cDCE, and VC, with the exception of a low-level detection of TCE at the furthest downstream sample where the Area 41 plume discharges to the WFQC (sample QC-5). TCE at QC-5 was measured at the reporting limit of 0.020 µg/L, which is below the surface water RBSL of 3,000 µg/L.

The following sections describe each plume in more detail. Groundwater plume figures for each AOC (Figures 6 through 11) show the extent of plumes exceeding the PRG (see Section 2.3); each figure shows the maximum extent of the plume (yellow shaded area) and current extent of the plumes (green dashed line) based on current data through July 2022. In areas where only TCE exceeds the PRGs (Area 1, Area 41, and Admin Area) the associated figure shows the extent of the TCE plume. In Area 8, where only VC exceeds the PRG, the VC plume is shown. In Areas 5 and 34 where breakdown products cDCE and VC exceed or have historically exceeded the PRGs, a combined plume extent is shown for TCE plus breakdown products.

1.4.2.1 Area 1

The Area 1 AOC consists of a long, narrow TCE plume in shallow groundwater, approximately 5 acres in maximum extent. The plume source is most likely non-point source releases to the ground at the former test pad. The plume originates near the former concrete test pad and extends approximately 1,200 ft downgradient (southeast) toward 27th Avenue. The current (July 2022) maximum TCE concentration of 76.6 micrograms per liter ($\mu\text{g/L}$) occurs approximately 350 ft downgradient of the former test pad. The plume has a maximum width of approximately 300 ft, and the depth of groundwater impacts is approximately 25 to 30 ft bgs. The Area 1 plume is shrinking under natural conditions, with concentration reduction occurring at the head of the plume, as shown on Figure 6. The current extent of the TCE plume greater than the PRG (through July 2022) is approximately 16 percent less than the maximum historical extent.

The plume is naturally aerobic with minor cDCE production occurring in siltier layers/lenses having iron-reducing redox. Limited cDCE is currently detected at low concentrations of 0.60 and 1.35 $\mu\text{g/L}$. The next sequential breakdown product, VC, is not detected.

1.4.2.2 Area 5

The Area 5 AOC consists of a TCE plume (currently 5.22 acres) and smaller breakdown product plumes that extend through the eastern portion of Area 4 and into Area 9. The plume source is most likely non-point source releases to the ground at the former test pad. The plume originates at the former test area and extends approximately 900 ft downgradient beneath Coho Creek and West Security Road. The current (July 2022) maximum TCE concentration of 248 $\mu\text{g/L}$ occurs near West Security Road approximately 450 ft downgradient of the former source area. The Area 5 plumes start relatively shallow (less than 30 ft bgs) and extend deeper (60 to 90 ft bgs) downgradient beyond Coho Creek. The maximum and current extents of combined plumes in Area 5 are shown on Figure 7. The current combined plume extent greater than the PRG (through July 2022) is approximately 27 percent less than the maximum historical extent.

The plume is naturally anaerobic and iron-reducing, consistent with detections of cDCE prior to pilot testing. Bioremediation pilot testing was performed near TGW-043 and along the plume centerline in 2004 through 2006 and resulted in production of VC. Currently, smaller cDCE and VC plumes originate

within, and extend beyond, the TCE plume. The current maximum concentration of cDCE is 448 µg/L, and cDCE only exceeds PRGs at two monitoring wells. The VC plume is approximately 1.59 acres and has a current maximum concentration of 15.3 µg/L.

Based on RI evaluation of groundwater/surface water interaction, Area 5 groundwater discharges seasonally to Coho Creek. Groundwater discharge to the creek occurs during winter months when groundwater elevations are somewhat higher than the creek water level. Conversely in summer months, the creek discharges to the aquifer; this summer losing condition of the creek results in a downward vertical gradient which pushes the plumes deeper to east of the creek. Despite seasonal discharge of groundwater to Coho Creek, COCs were not detected in surface water samples collected from 1999 through 2017.

1.4.2.3 Area 8

The Area 8 AOC consists of a shallow VC plume, approximately 5.45 acres in maximum extent. The plume source is most likely non-point releases of TCE to the ground near former Building 16-407 located at the head of the plume. Biodegradation has progressed such that VC is the predominant COC in the Area 8 plume. The current (July 2022) maximum VC concentration of 7.95 µg/L occurs approximately 500 ft downgradient of the former Building 16-407. Well TGW-132 marks the distal (east) end of the plume and VC concentrations at this well are periodically above and below the PRG. The maximum VC concentrations are found at depths from approximately 10 to 40 ft bgs. The Area 8 plume is shrinking under natural conditions, as shown from the maximum and current plume extents greater than the PRG on Figure 8. The current extent of the VC plume greater than the PRG (through July 2022) is approximately 80 percent less than the maximum historical extent.⁸

Conditions in this plume are naturally anaerobic and TCE has been reduced to VC such that only VC exceeds the PRG. Biodegradation in Area 8 may have been caused by natural organic carbon and/or organic carbon from an old septic drain field. The higher concentrations of breakdown products VC compared to TCE indicate effective reductive dechlorination over many years since the release occurred.

1.4.2.4 Area 34

The Area 34 AOC consists of historical TCE and cDCE plumes with a combined area of approximately 3.5 acres. The plume sources were the ST-2 septic tank/drain field and discharges to ground near the vacuum and aspirator tank area. The septic tank and contents were removed in 1998/1999. The plume extends south and east to East Security Road, approximately 1,040 ft. Bioremediation pilot and treatability testing were conducted between 2000 and 2017, causing VC production. The current extent of the VC plume (3.6 acres) is approximately the same as the 3.5-acre-baseline TCE/cDCE plume extent. The historical and current plume extents are shown on Figure 9.

⁸ Maximum extent was from monitoring wells installed in this area in 2018.

Prior to bioremediation treatability testing, the plume was naturally anaerobic iron-reducing, consistent with substantial detections of cDCE. Following bioremediation treatability testing no TCE or cDCE remain above the PRGs due to degradation to VC and ethene/ethane; VC was above the PRG at about 60 percent of the wells. However, the maximum VC concentration in the final treatability test sampling event was just 12 percent of the peak concentration during treatability testing and non-toxic end products ethene/ethane were detected at every well where VC remained above the PRG. VC concentrations are expected to further decrease over time through natural attenuation. Methanogenic redox conditions were established during the treatability test, consistent with VC and ethene/ethane production.

The groundwater plume in Area 34 appears to end prior to the East Security roadside ditch, but surface water samples were collected from the ditch to evaluate potential plume discharge. Despite seasonal groundwater discharge to the ditch, COCs were not detected in surface water sampled in 2010 and 2017.

1.4.2.5 Area 41

The Area 41 AOC consists of a 42-acre TCE plume. The source of TCE in Area 41 is unknown but is likely a result of non-point source releases; no tanks or specific processes were identified that used TCE within this area. The plume originates east of 27th Avenue and encompasses all three former test pads and the eastern portion of the former control house. The plume extends east beneath the Seattle Premium Outlets property, the I-5 ROW, and an undeveloped private parcel before flowing east to discharge to the WFQC. The current (July 2022) maximum TCE concentration of 94.2 µg/L occurs near 30th Avenue, approximately 1,000 ft downgradient of the head of the plume. The extent of the TCE plume is approximately 3,200 ft (0.6 miles) long and 600 ft wide, with the depth of groundwater impacts from 10 to 70 ft bgs. The plume appears to be stable as shown on Figures 10A and 10B. No shrinking of the plume has been observed since monitoring wells were installed in 2018.

The Area 41 plume is aerobic. Detections of the TCE breakdown product cDCE at relatively low concentrations (maximum concentration of 8.85 µg/L) and occasional VC detections (maximum detection of 0.10 µg/L) are consistent with reducing conditions within discrete silty layers/lenses within the sand aquifer. The Area 41 plume is stable and ends at the WFQC. Boundary wells, located north and south of the plume before it passes underneath the I-5 ROW, have been consistently non-detect for COCs since installation.

The plume discharges completely to the WFQC based on evidence of year-round gaining stream conditions and the results of groundwater sampling east of the creek. Groundwater sampling data indicate that TCE is present in groundwater to the east of I-5 but is not present in the borings located east of the WFQC. Concentrations and the exact flow path of TCE in the area in between the two groups of borings near the WFQC are not defined due to steep slopes and riparian wetlands which prevent drilling access. COCs were not detected in surface water sampled in 2019 with the exception

of the southern-most sampling location (QC-5) where TCE was detected at the reporting limit (0.020 µg/L), which is below the surface water RBSL of 3,000 µg/L.

1.4.2.6 Administration Area

The Admin Area AOC consists of a TCE plume, approximately 15 acres in maximum extent. The plume originates near former Building 16-353 and extends beneath I-5, beneath a property east of I-5 that is owned by the Tribes, then discharges to the WFQC. The sources of TCE in the Admin Area were the former septic tank, which contained elevated levels of TCE in the sludge, and the former industrial drain field; both sources were removed through IRAs occurring between 1998 and 2001 and in 2009, respectively. The current (July 2022) maximum TCE concentration of 42.8 µg/L occurs approximately 1,200 ft downgradient of the former source areas. The plume is approximately 2,000 ft long and 500 ft across with a depth of groundwater impacts between 15 and 60 ft bgs. The plume extent is shrinking at both the head and distal end, as shown on Figure 11. The current extent of the TCE plume (through July 2022) is approximately 66 percent less than the maximum historical extent. Substantial decreases in TCE concentrations and plume extent over time indicate significant natural attenuation of the Admin Area plume following source removal actions.

The plume is aerobic with an isolated exception where natural peat deposits occur near the WFQC. A single monitoring well (TGW-068) located in naturally occurring peat has detections of cDCE with concentrations below the PRG and VC concentrations are above PRG. Breakdown products cDCE and VC have not been detected in groundwater except at this well and in nearby seeps.

The plume discharges completely to the WFQC based on evidence of year-round gaining stream conditions and the results of groundwater sampling east of the creek. Groundwater sampling data indicate that TCE is present in groundwater to the east of I-5 but is not present in the borings located east of the WFQC. COCs were not detected in creek surface water collected in 2017.

2.0 IDENTIFICATION OF REMEDIAL ACTION OBJECTIVES

This section discusses the ARARs and the RAOs for the Site.

2.1 Remedial Action Objectives

RAOs define the goals of the cleanup that must be achieved to adequately protect human health and the environment. The RAOs are based on the conclusions of the BRA, which identified construction workers and commercial workers in future buildings as the only receptors with potentially unacceptable future risk. The following RAOs are proposed for the FS:

- RAO-1: Prevent exposure to contaminated groundwater above PRGs for protection of construction worker incidental ingestion/direct contact.
- RAO-2: Reduce groundwater COC concentrations below the site PRGs to their expected beneficial uses where feasible (aquifer restoration).⁹
- RAO-3: Prevent commercial worker exposure to COCs above PRGs in indoor air due to potential vapor intrusion to future buildings over the plumes.

2.2 Applicable or Relevant and Appropriate Requirements

Cleanup actions must comply with ARARs; ARARs include applicable, relevant, and appropriate state, local, and federal laws, standards, and guidance. Tribal Reservations are not subject to Washington State regulations. However, state regulations may be considered in the development of cleanup and remedial action levels.

Applicable requirements are those that are specifically applicable to actions, chemicals, or circumstances at the site, while relevant and appropriate requirements are those that are not specifically applicable but address actions, chemicals, or circumstances that are similar to those at the site. Attainment of ARARs is one of the two threshold criteria set by the National Contingency Plan (NCP) for evaluation of remedial alternatives. Cleanup technologies identified below will be developed and screened based on their potential application in remediation of the Site. Compliance with the ARARs will be considered as a part of the effectiveness and implementability evaluation for each remedial technology. Each cleanup process option, as well as the overall Site cleanup action, will be evaluated for compliance with ARARs. Preliminary ARARs that will be further evaluated in the FS are presented in Table 3.

2.3 Groundwater Preliminary Remediation Goals

The proposed PRGs are developed for COCs identified in groundwater, based on potential future risk pathways and ARARs. Based on a comparison of risk-based groundwater concentrations protective of

⁹ Commercial workers represent the receptor most affected by potential use of impacted groundwater as drinking water and were, therefore, the basis for risk assessment. Any exposure to groundwater as drinking water by the general public would be at a much lower frequency and duration. Levels protective of commercial worker are also protective of the general public.

the various potential future risk pathways (construction worker—dermal and incidental ingestion, commercial worker—drinking water and indoor air) and ARARs, the federal MCLs for drinking water are proposed as the PRGs. The MCLs are lower (more protective) than the calculated concentrations protective of cancer risk (target cancer risk of 10^{-5}) and non-cancer risk (target hazard quotient of 1). The federal MCLs under the Safe Drinking Water Act also match the Tribal Drinking Water standards. Risk values, ARARs, and proposed PRGs are presented for comparison for each COC in Table 4.

Proposed PRGs will be used through the FS until becoming final cleanup levels in the Record of Decision (ROD). The proposed PRGs apply in each of the six plume areas including in Area 8 and Area 34 where no unacceptable risk was demonstrated by the BRA. Proposed PRGs are as follows:

- TCE = 5 µg/L
- cDCE = 70 µg/L
- VC = 2 µg/L

2.4 Indoor Air PRGs and Action Levels

Vapor intrusion to indoor air is not a current risk at the Site, as demonstrated by 2021 and 2022 indoor air results for Admin Area Building 16-368 (Landau and Pioneer 2022), which were below the proposed indoor air PRGs for TCE and breakdown products cDCE and VC. This Admin Area building is the only occupied building at the Site existing over COC contamination of shallow groundwater. Although the Area 41 plume extends beneath commercial buildings at and near the Seattle Premium Outlet Mall property, soil vapor intrusion is not a complete pathway because TCE and breakdown products cDCE and VC are not present in the shallowest groundwater sampled at the water table.

Boeing will coordinate with the Tribes during construction planning for future occupied buildings constructed over the groundwater plumes to evaluate potential vapor intrusion concerns. TCE and VC are drivers for indoor air risk.¹⁰ Because the future building(s) will not yet be present to measure COC concentrations in actual indoor air, groundwater and soil vapor data will be compared to action levels protective of indoor air. Groundwater sampled from near the water table will be compared to groundwater action levels, which are protective of indoor air and based on the proposed indoor air PRG. Similarly, soil vapor results will be compared to soil vapor action levels, also based on the proposed indoor air PRG. Groundwater action levels, soil vapor action levels, and proposed indoor air PRGs are calculated using the EPA vapor intrusion screening levels calculator (EPA 2020) based on a target cancer risk of 10^{-6} , a target hazard quotient of 1, groundwater temperature of 11 degrees Celsius, and the default commercial exposure scenarios. The groundwater action levels, soil vapor action levels, and proposed indoor air PRGs are presented for TCE and VC in Table 5. Where action levels are exceeded, engineering controls will be considered on a case-by-case basis (e.g., vapor barriers, crawl space ventilation).

¹⁰ cDCE is not a risk-driver in air because of its lower toxicity.

2.5 Screening During Redevelopment

It is possible that unknown releases may be encountered as part of redevelopment activities at the Site in locations where Boeing conducted former operations. For redevelopment activities, it is anticipated that Boeing support could include screening soil or groundwater with standard field screening techniques for contamination, sampling and analysis for contaminant identification and quantification, and sampling for waste characterization and management. If required, sampling will be performed in accordance with the Site quality assurance project plan (QAPP; Landau 2017a). Soil and groundwater analytical results will be compared to the EPA regional screening levels, which were adopted as Site RBSLs during the RI and presented as Appendix L of the RI Summary Report (Landau 2017b). Comparison to the Site RBSLs will guide delineation and potential cleanup of impacted soil or groundwater, if encountered.

3.0 IDENTIFICATION AND SCREENING OF REMEDIAL ACTION TECHNOLOGIES

This section identifies and screens potential remedial action technologies that are available and may be appropriate for cleanup of the groundwater AOCs at the Site. As outlined in EPA guidance (EPA 1988), the intent of this step is to screen out cleanup technologies that are not appropriate or suitable to site conditions or constraints and to narrow down the potential candidate cleanup technologies to those that will be assembled into remedial action alternatives for comparative analysis in the FS report.

Remedial technologies were identified and grouped into general response actions (GRAs) based on known Site conditions, media impacted, contaminant types, and Landau's best professional judgement of applicable remedial technologies. The following documents were used to assist in identifying and screening remedial action technologies at the Site:

- Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA 1988)
- Considerations in Ground-Water Remediation at Superfund Sites and RCRA (Resource Conservation and Recovery Act) Facilities—Update (EPA 1992b)
- Presumptive Response Strategy and *Ex-Situ* Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance (EPA 1996)
- Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites (EPA 1999).

Technologies selected for this evaluation were screened based on effectiveness, implementability, and cost. Technologies were screened out or retained for further evaluation and incorporation into the cleanup alternatives developed in the FS. Common factors that influence the technology selection and screening process include contaminant type and concentration, subsurface and other conditions (e.g., depth of contamination, geologic matrix, location of site infrastructure), and access constraints. Technologies that would clearly not be applicable or effective for the Site COCs or conditions, or that would be clearly cost prohibitive, were excluded from the screening evaluation. Because DNAPL sources do not exist at the Site, technologies applicable to DNAPL treatment (e.g., co-solvent flushing, *in situ* thermal treatment) are excluded or screened out. Given the decades since TCE was released at Site test areas, the most applicable technologies are those well suited to address contaminant matrix back diffusion. Tables 6A (soil vapor) and 6B (groundwater) present applicable technologies, screening, and decision criteria for affected contaminant media at the Site. The technologies retained for evaluation in the FS include:

- **No action** is retained as required under CERCLA FS guidance for comparison to the other developed alternatives.
- **Institutional controls** to limit use of groundwater as drinking water.

- **Vapor intrusion engineering controls** (e.g., vapor barrier) for future buildings located over plumes where vapor intrusion may be a concern.
- **Monitored natural attenuation (MNA)** either as a standalone technology or as a subsequent treatment after active groundwater treatment. Phyto-attenuation is a component of MNA for plumes that extend beneath existing forest and forested wetlands which may be excluded from future development (e.g., Area 1, Area 34, distal portion of Admin Area plume).
- **Anaerobic enhanced *in situ* bioremediation (EISB)** in plumes which may require active treatment where limited biodegradation is occurring.
- ***In situ* chemical reduction (ISCR)** through addition of ferrous sulfate as concurrent and complementary treatment to EISB. Not applicable for treatment of only VC concentrations in groundwater.
- **Dynamic groundwater recirculation (DGR)** in plumes which may require active treatment where limited biodegradation is occurring and groundwater concentrations do not show a decreasing trend. This technology is not included in the evaluation for plumes where substantial plume treatment or source removal has already occurred and concentrations are decreasing (Area 8, Area 34, Admin Area).

4.0 PROPOSED REMEDIAL ALTERNATIVES

This section summarizes proposed alternatives for each AOC category to be evaluated in the FS. Table 7 presents a final list of technologies that will be carried forward to the FS for each AOC. The applicability of each technology is described above. Table 7 also shows how the AOCs are grouped into four categories where the same technologies will be evaluated. The AOCs are grouped as follows:

- Category A (Areas 1, 5, and 41): Stable groundwater plumes where limited natural biodegradation to cDCE is occurring and without clear decreasing cVOC concentration trends observed during the RI.
- Category B (Admin Area): Naturally aerobic plume where groundwater cVOC concentrations are decreasing and the plume area has shrunk substantially since completion of source removal actions.
- Category C (Area 34): Shrinking groundwater plumes where treatability testing has resulted in degradation of TCE through cDCE to VC. TCE and cDCE are below PRGs. VC concentrations remain above PRGs at approximately 60 percent of wells but are decreasing.
- Category D (Area 8): Shrinking groundwater plume where natural biodegradation has resulted in reduction of TCE through cDCE to VC. TCE and cDCE are below PRGs, and VC concentrations exceed the PRG at two wells; the distal well is periodically below the PRG.

The proposed alternatives for each group are presented in four tables corresponding to the plume categories above:

- Table 8A (for Category A)
- Table 8B (for Category B)
- Table 8C (for Category C)
- Table 8D (for Category D).

5.0 FEASIBILITY STUDY SCHEDULE AND OUTLINE

In accordance with the ASAOC, the draft FS report will be submitted within 120 days after EPA approval of this FS work plan. The FS report will be prepared presenting the evaluation of remedial site alternatives and the recommended alternative. The outline of the FS report, presented below, is consistent with the Statement of Work (SOW) of the ASAOC (EPA 2010) with additional detail and descriptions added. FS section numbers are presented below. The italicized text within each FS report section describes the information that will be included in the section and the methods and processes that will be used in that section. For example, a description of how the comparative analysis of remedial action alternatives will be completed is described under FS5.0.

Executive Summary

FS1.0 Introduction

FS2.0 Background

FS2.1 Site Description

FS2.1.1 Site Location and Description

FS2.1.2 Site Operations and History

FS2.1.3 Site Topography and Surface Drainage

FS2.1.4 Site Geology and Hydrogeology

FS2.2 Previous Investigations and Interim Actions

Includes citations of previously prepared documents and environmental investigations

FS2.3 Current and Future Site Use

FS2.4 Conceptual Site Model

FS3.0 Remedial Action Goals and Objectives

FS3.1 Remedial Action Objectives

FS3.2 Applicable or Relevant and Appropriate Requirements

FS3.3 Cleanup Level Goals

FS3.4 Remedial Action Schedule

FS4.0 Analysis of Remedial Action Alternatives

FS4.1 Summary of Technology Screening

A summary of the technology screening as included in the FSWP.

FS4.2 Assembled Remedial Action Alternatives

A summary of the assembled remedial action alternatives as included in the FSWP.

FS5.0 Comparative Analysis of Remedial Action Alternatives

Comparative analysis will include the following parameters for comparison:

- *Overall protection of human health and the environment*
- *Short-term effectiveness*
- *Long-term effectiveness and permanence*
- *Reduction of toxicity, mobility, or volume through treatment*
- *Implementability*
- *Compliance with ARARs*
- *Costs*
- *Community Acceptance*

FS6.0 Recommendation of Preferred Remedial Action Alternative

FS7.0 References

6.0 USE OF THIS REPORT

This report has been prepared for the exclusive use of Boeing, the Tribes, and the EPA for specific application to the former Boeing-Tulalip Test Site in Marysville, Washington. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of Landau. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by Landau, shall be at the user's sole risk. Landau warrants that within the limitations of scope, schedule, and budget, our services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. We make no other warranty, either express or implied.

7.0 REFERENCES

- Boeing. 1992. Tulalip Test Facility Parcel 3, Marysville, Washington, Lease Termination Environmental Assessment. The Boeing Company. August 17.
- Ecology. 2015. Well Log Database Search. Washington State Department of Ecology. August.
- EPA. 1988. Interim Final: Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. EPA/540/G-89/004. US Environmental Protection Agency. October.
- EPA. 1992a. Guidance for Data Useability in Risk Assessment (Part A). US Environmental Protection Agency, Office of Emergency and Remedial Response. April.
- EPA. 1992b. Memorandum: Considerations in Ground-Water Remediation at Superfund Sites and RCRA Facilities—Update. US Environmental Protection Agency, Office of Solid Waste and Emergency Response. May 27.
- EPA. 1996. Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance. EPA 540-R-96-023. US Environmental Protection Agency. October.
- EPA. 1999. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. Publication No. 9200.4-17P. US Environmental Protection Agency, Office of Solid Waste and Emergency Response. April 21.
- EPA. 2010. Administrative Settlement Agreement and Order on Consent for Remedial Investigation/Feasibility Study, Boeing Tulalip Test Site, Snohomish County, Washington. US Environmental Protection Agency, Regional 10, CERCLA Docket No. 10-2010-0245. September 27.
- EPA. 2020. Vapor Intrusion Screening Level (VISL) Calculator. US Environmental Protection Agency. https://epa-visl.ornl.gov/cgi-bin/visl_search. July 24.
- Golder. 1998. Final Scope of Work for the Investigation of Potential Environmental Concerns at the Tulalip Test Site, Marysville, Washington. Golder Associates.
- Landau. 2000. Beneficial Water Use Survey, Tulalip Test Site. Landau Associates, Inc. August 3.
- Landau. 2001. Technical Memorandum: Groundwater Model, Boeing Tulalip Test Site. Landau Associates, Inc. October 26.
- Landau. 2011. Technical Memorandum: Final Report, Area 34 Bioremediation Pilot Testing, Former Boeing Tulalip Test Site, Marysville, Washington. Landau Associates, Inc. July 6.
- Landau. 2017a. Data Gaps Investigation Work Plan, Former Boeing Tulalip Test Site, Marysville, Washington. Landau Associates, Inc. July 18. (Note: The Site QAPP is contained in Appendix D.)
- Landau. 2017b. Remedial Investigation and Summary of Existing Information Report, Former Boeing-Tulalip Test Site, Marysville, Washington. Landau Associates, Inc. May 8. (Note: The BRA Work Plan is contained in Appendix Q.)
- Landau. 2020. Data Gaps Investigation Report. Former Boeing-Tulalip Test Site, Marysville, Washington. Landau Associates, Inc. October 22.
- Landau. 2021a. Addendum No. 3. Baseline Risk Assessment Work Plan. Former Boeing-Tulalip Test Site, Marysville, Washington. Landau Associates, Inc. January 13.

Landau. 2021b. Addendum No. 4. Baseline Risk Assessment Work Plan. Former Boeing-Tulalip Test Site, Marysville, Washington. Landau Associates, Inc. April 14.

Landau. 2021c. Final Completion Report, Area 34 Bioremediation Treatability Testing, Boeing-Tulalip Test Site, Marysville, Washington. Landau Associates, Inc. October 5.

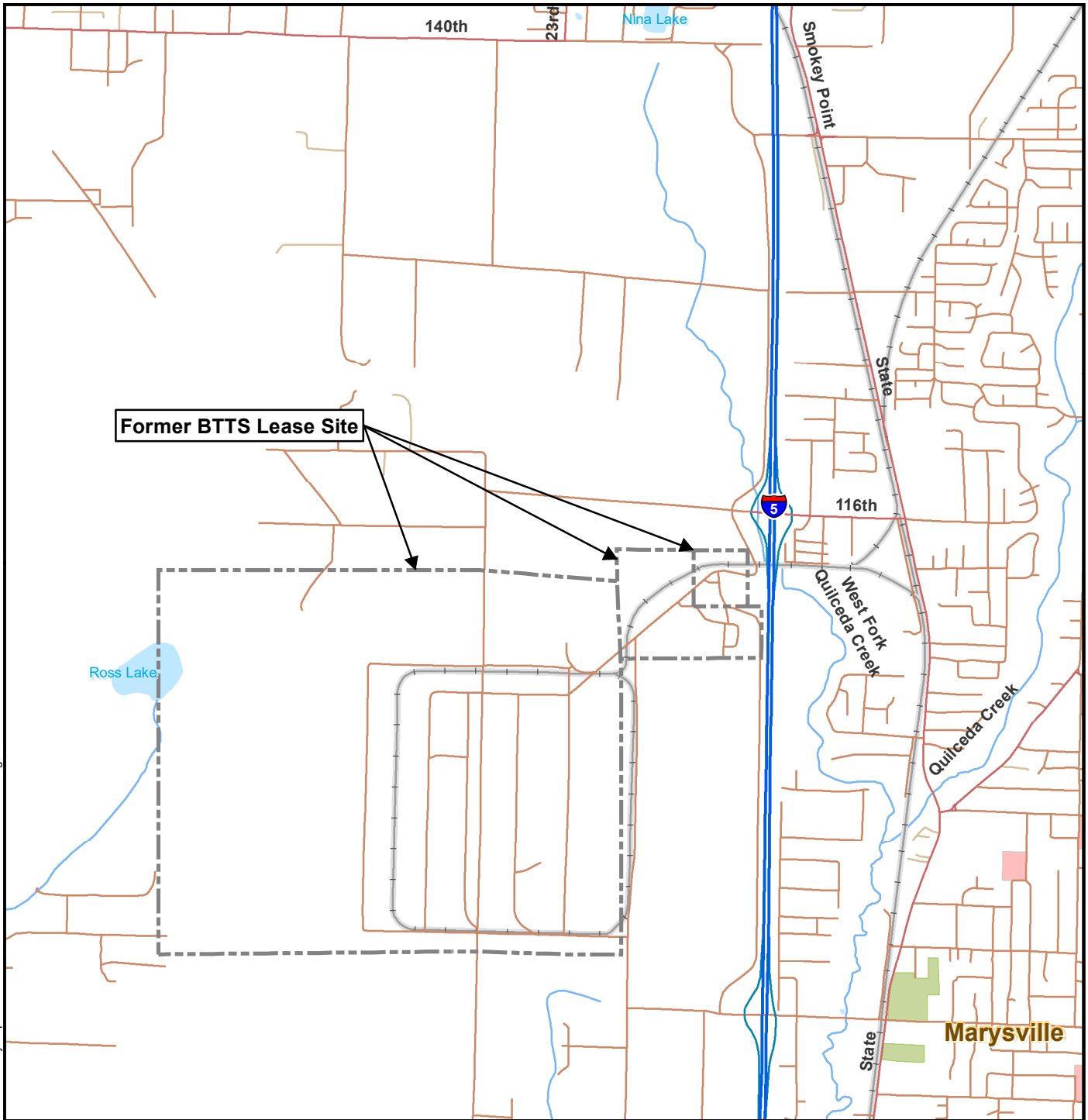
Landau and DHEC. 2020a. Technical Memorandum: Addendum No. 1, Baseline Risk Assessment Work Plan, Former Boeing-Tulalip Test Site, Marysville, Washington. Landau Associates, Inc. and DH Environmental Consulting. June 16.

Landau and DHEC. 2020b. Technical Memorandum: Addendum No. 2, Baseline Risk Assessment Work Plan, Former Boeing-Tulalip Test Site, Marysville, Washington. Landau Associates, Inc. and DH Environmental Consulting. November 17.

Landau and Pioneer. 2022. Baseline Risk Assessment, Former Boeing-Tulalip Test Site. Landau Associates, Inc. and PIONEER Technologies Corporation. July 19.

Tulalip Tribes. 2009. Comprehensive Land Use Plan. Prepared by the Tulalip Tribes Community Development Department and the Tulalip Tribes Planning Commission. September.

G:\Projects\025087022\012\Feeability Study Work Plan\F01 VicinityMap.mxd 7/11/2022 NAD 1983 StatePlane Washington North FIPS 4601 Feet



Abbreviations
BTTs Boeing Tulalip Test Site

Data Source: ESRI 2006

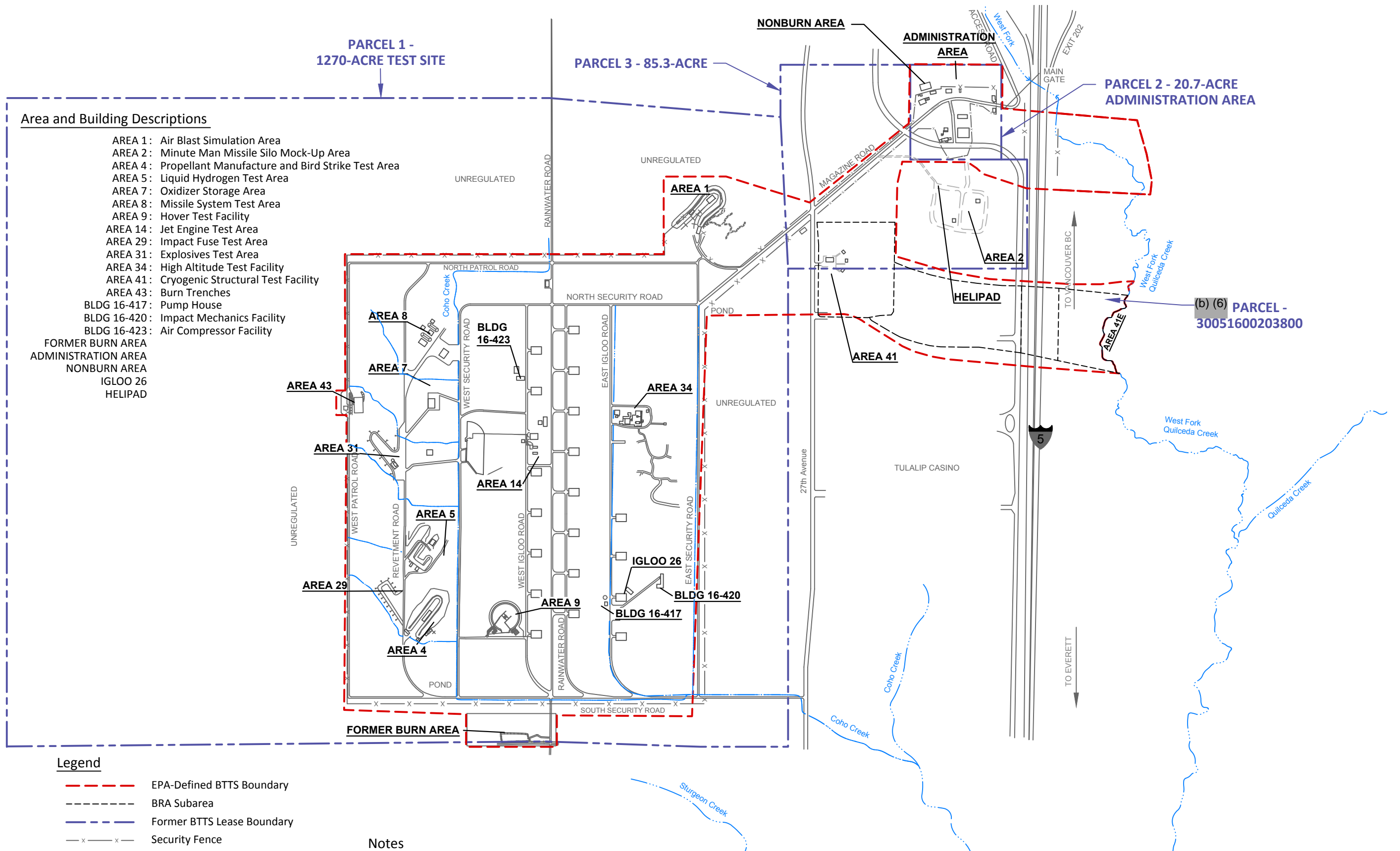


Boeing Tulalip Test Site
Marysville, Washington

Vicinity Map

Figure
1

Landau Associates | G:\Projects\025\087\023\012\FSWP\F02 Former Boeing Tulalip Test Site.dwg | 1/10/2023 9:12 PM | ezick



Area and Building Descriptions

AREA 1: Air Blast Simulation Area
AREA 2: Minute Man Missile Silo Mock-Up Area
AREA 4: Propellant Manufacture and Bird Strike Test Area
AREA 5: Liquid Hydrogen Test Area
AREA 7: Oxidizer Storage Area
AREA 8: Missile System Test Area
AREA 9: Hover Test Facility
AREA 14: Jet Engine Test Area
AREA 29: Impact Fuse Test Area
AREA 31: Explosives Test Area
AREA 34: High Altitude Test Facility
AREA 41: Cryogenic Structural Test Facility
AREA 43: Burn Trenches
BLDG 16-417: Pump House
BLDG 16-420: Impact Mechanics Facility
BLDG 16-423: Air Compressor Facility
FORMER BURN AREA
ADMINISTRATION AREA
NONBURN AREA
IGLOO 26
HELIPAD

Legend

- EPA-Defined BTTS Boundary
- BRA Subarea
- Former BTTS Lease Boundary
- x-x- Security Fence
- AREA 8** Investigation Area

Abbreviations

BTTS Boeing Tulalip Test Site
EPA US Environmental Protection Agency

Notes

1. Most of the buildings and facilities shown have been demolished.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.



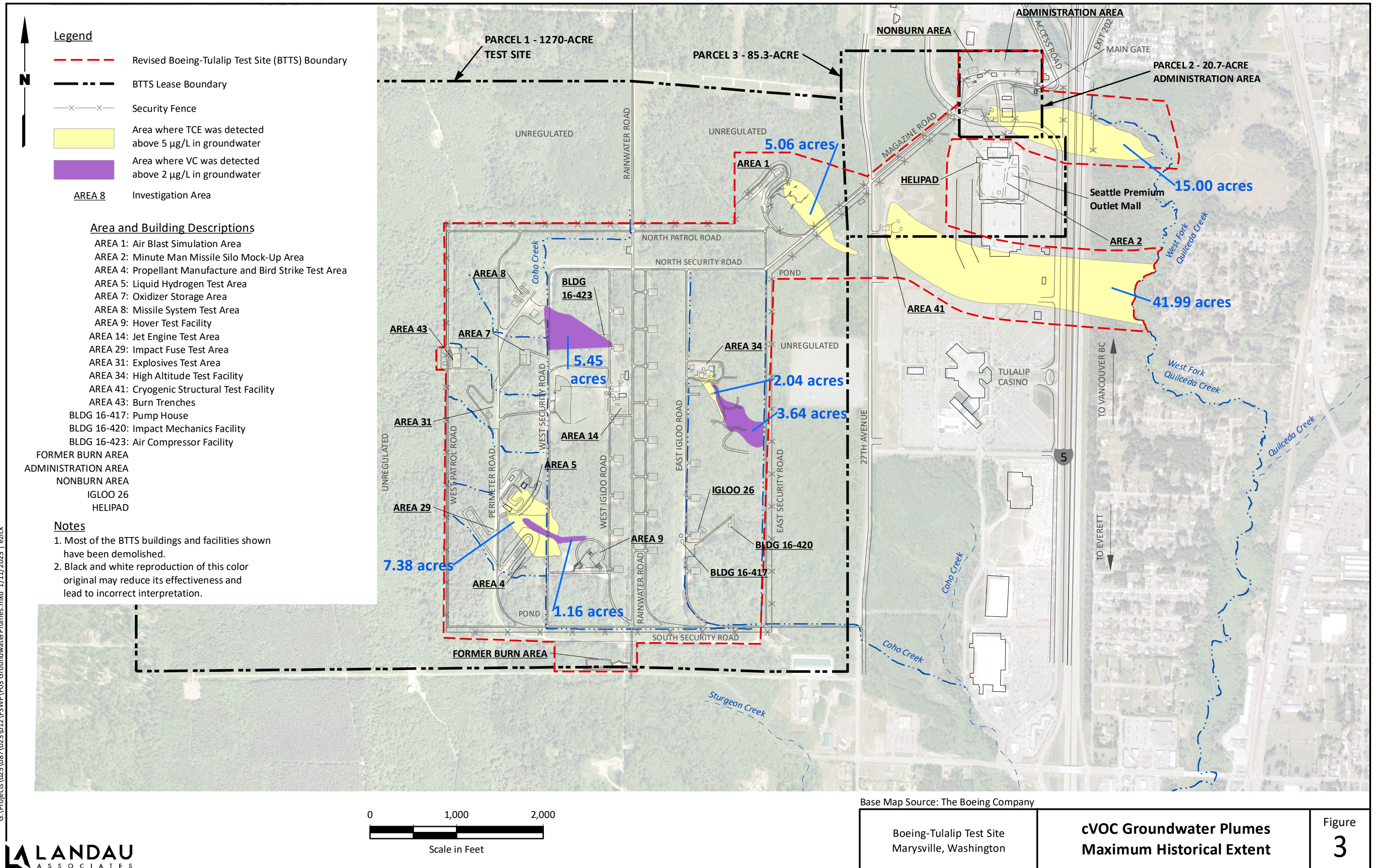
Base Map Source: The Boeing Company

Boeing Tulalip Test Site
Marysville, Washington

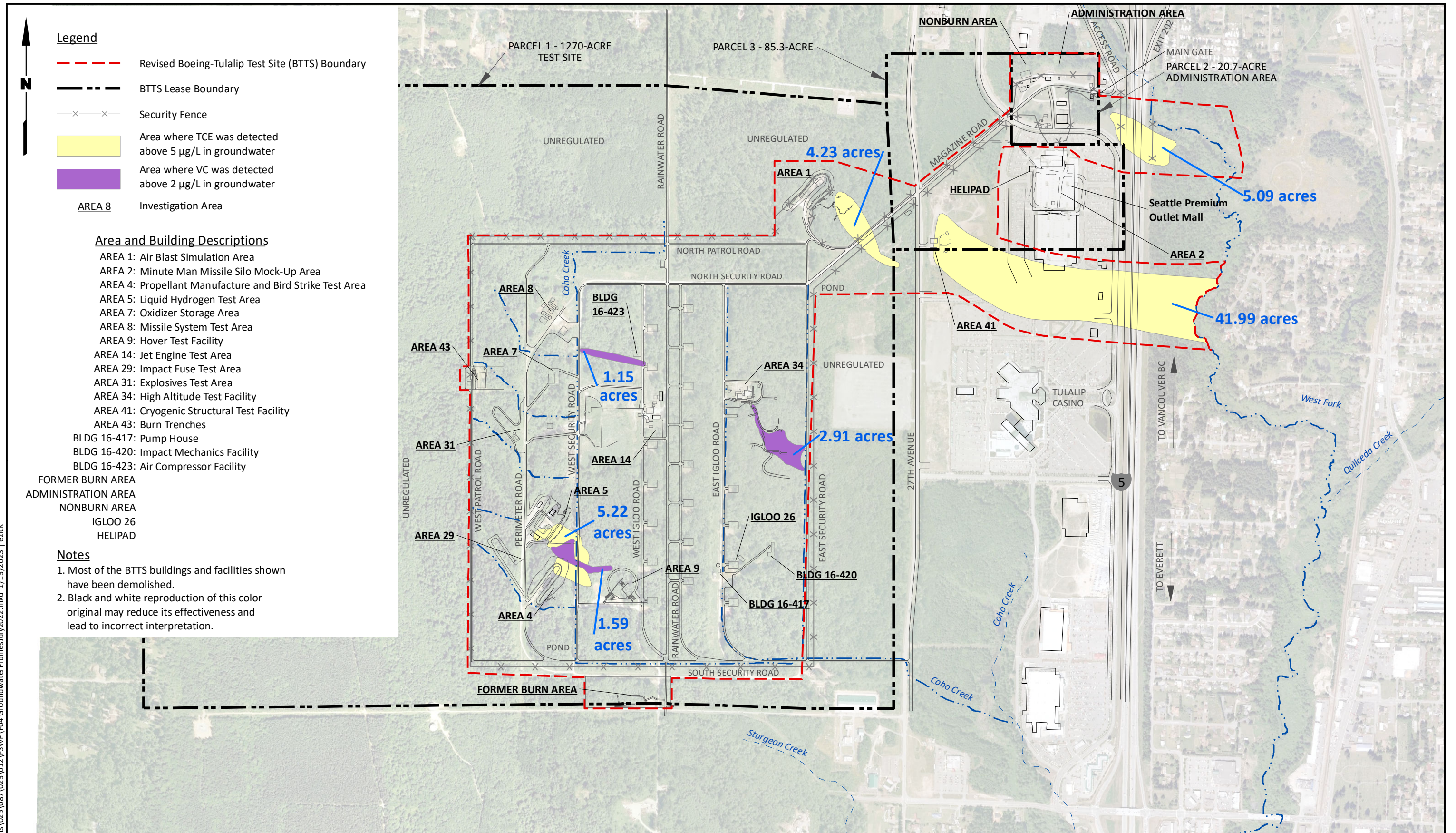
Former Boeing Tulalip Test Site

Figure
2

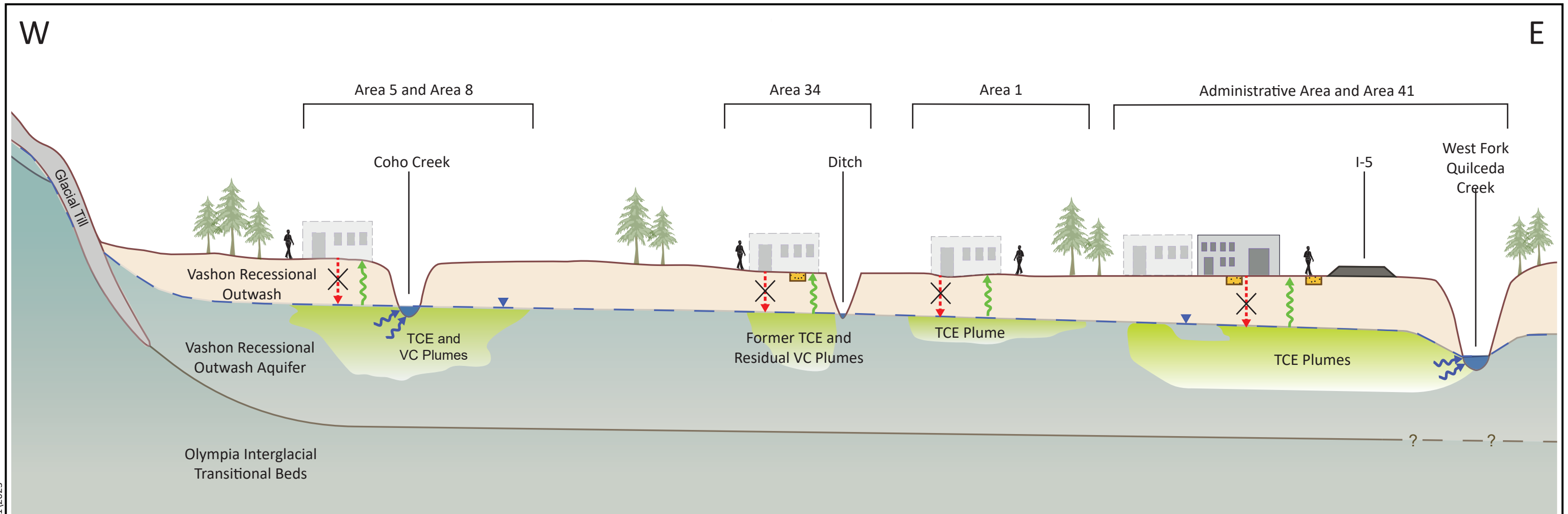
G:\Projects\025\087\023\012\F5WP\F03 GroundwaterPlumes.mxd 1/11/2023 | ezick



G:\Projects\025\087\023\012\F5WP\F04 GroundwaterPlumesJuly2022.mxd 1/13/2023 | ezick



Landau Associates, Inc. | G:\Projects\025\087\023\012\FSWP\F05 ConceptualSiteModel.ai | 01/11/2023



Legend

- Historic remedial excavation
- No persistent source area
- Potential vapor intrusion pathway
- Groundwater Discharge to surface water or transport from shallow soil to stormwater
- Existing commercial building
- Potential future commercial building

Area 5

Background:

- Unknown aqueous-phase TCE source.
- Seasonal discharge of GW to creek. (No TCE detected in creek.)

Area 8

Background:

- Unknown aqueous phase TCE source.
- TCE degraded to VC under natural conditions.

Area 34

Background:

- Aqueous-phase TCE release from septic tank (REMOVED) and atmospheric test area.
- Bioremediation treatability test resulting in conversion to degradation products.
- Seasonal discharge of groundwater to ditch (No TCE detected in ditch).

Area 1

Background:

- Unknown aqueous-phase TCE source.

Administrative Area

Background:

- TCE aqueous-phase release from septic tank (REMOVED) and industrial drain field (REMOVED).
- Plume discharges entirely to the West Fork Quilceda Creek (No TCE detected in creek).
- No indoor air risk in existing buildings

Area 41

Background:

- Unknown aqueous phase TCE source.
- Plume discharges entirely to the West Fork Quilceda Creek (No TCE detected in the creek).
- No indoor air risk in existing buildings.

Abbreviations

GW Groundwater
TCE Trichloroethene

Notes

1. CSM updated based on the conclusions of the approved Baseline Risk Assessment (BRA, Landau and Pioneer 2022).
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

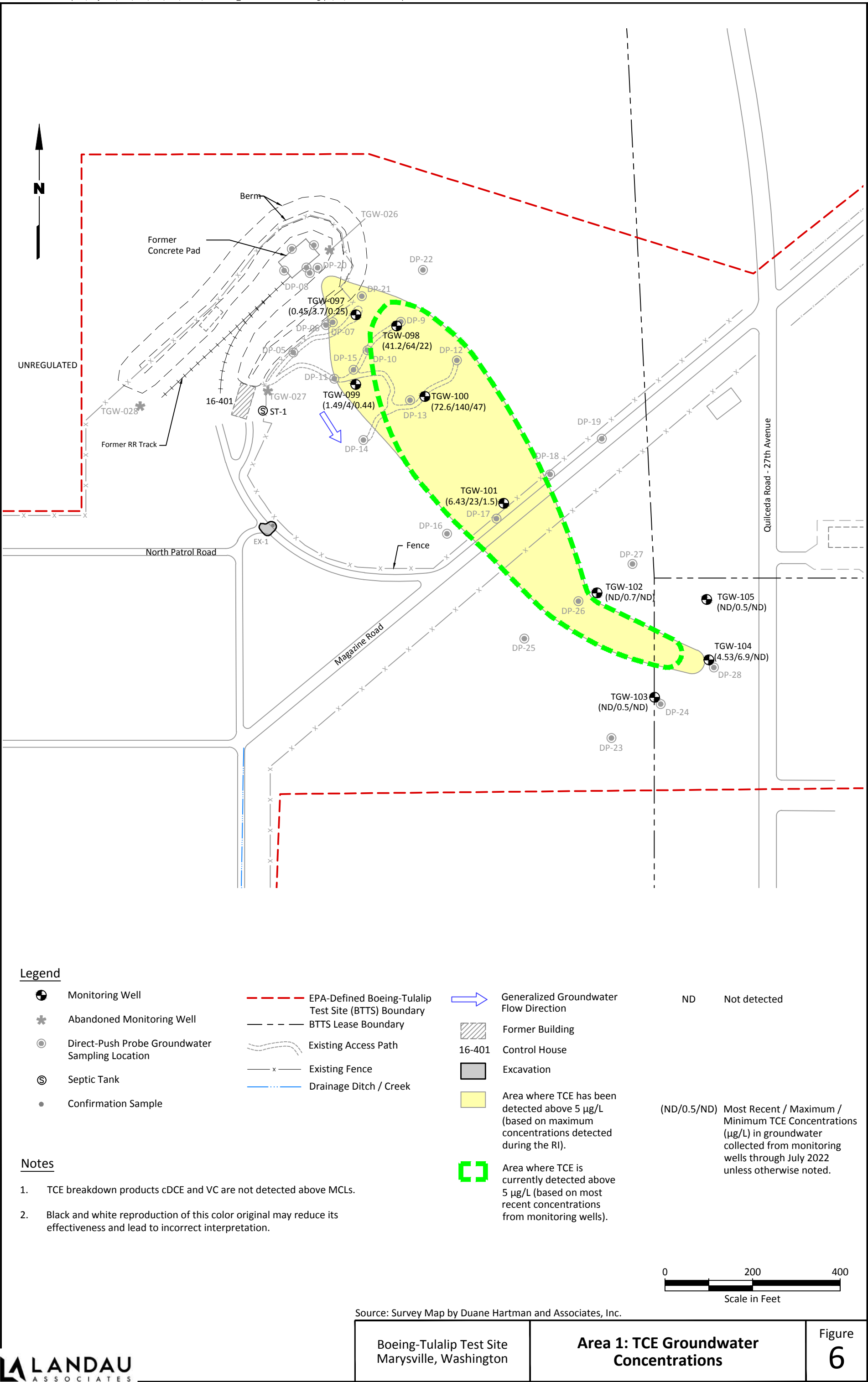
No current unacceptable site exposure risk. Future site development could result in the following complete exposure pathways with potential unacceptable risk:

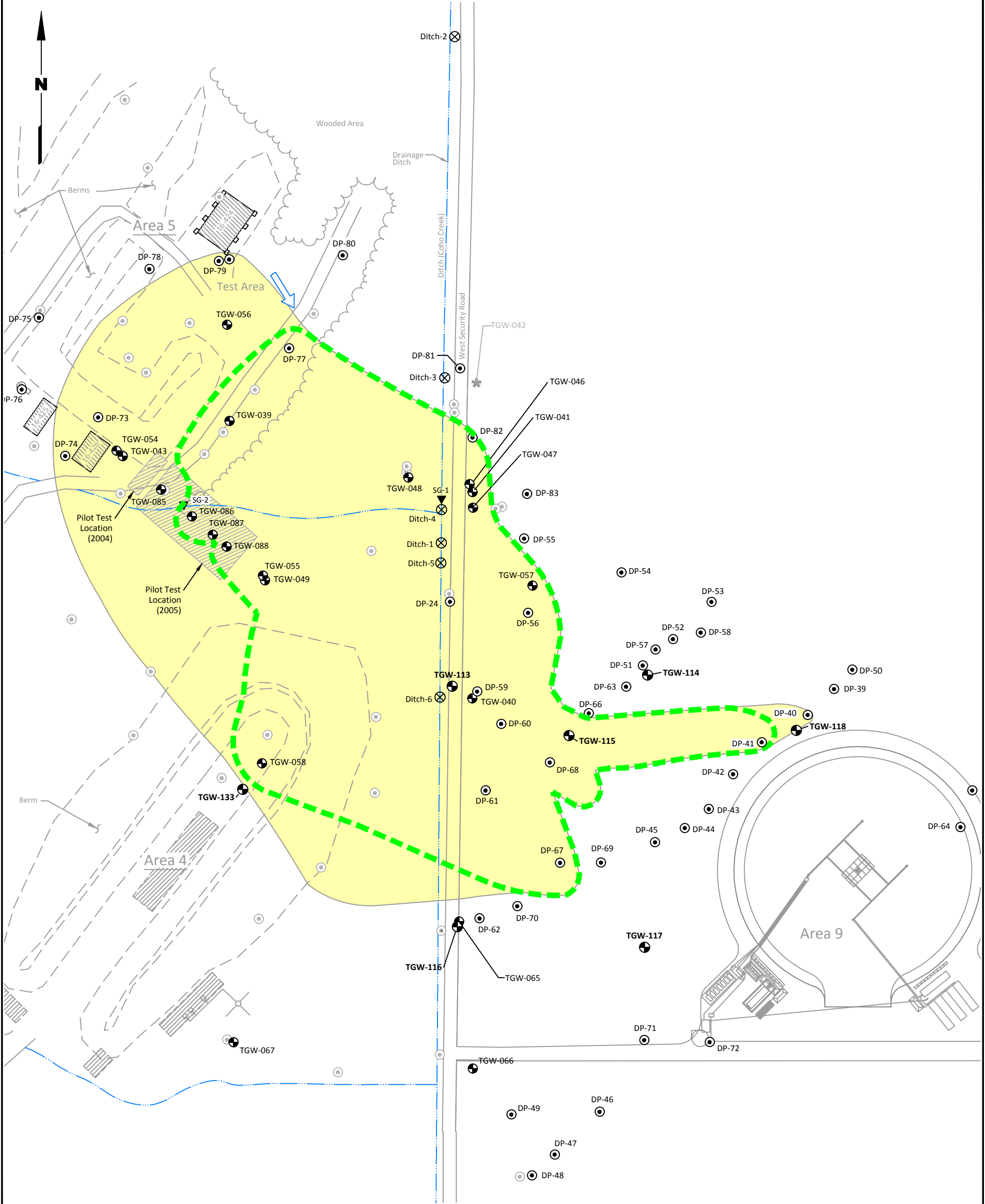
Human Receptors

Commercial Worker
Construction Worker

Potentially Complete and Significant Exposure Pathways

Groundwater - ingestion (used as drinking water)
Indoor Air- inhalation
Soil/Groundwater - incidental ingestion, dermal contact
Outdoor Air - inhalation





Legend

- Monitoring Well Location
- Data Gaps Direct-Push Probe Groundwater Sampling Location
- Direct-Push Probe Groundwater Sampling Location
- Abandoned Monitoring Well Location
- Surface Water Sample Location
- Stream Gauge
- Septic Tank

- Generalized Groundwater Flow Direction
- Approximate Location of Road
- Drainage Ditch / Creek
- Area where TCE > 5 µg/L, cDCE > 70 µg/L, and/or VC > 2 µg/L in Groundwater (based on maximum concentrations detected during the RI)
- Area where TCE > 5 µg/L, cDCE > 70 µg/L, and/or VC > 2 µg/L Currently in Groundwater (based on most recent concentrations (as of July 2022) from monitoring wells and Data Gaps direct-push borings)

Former Building

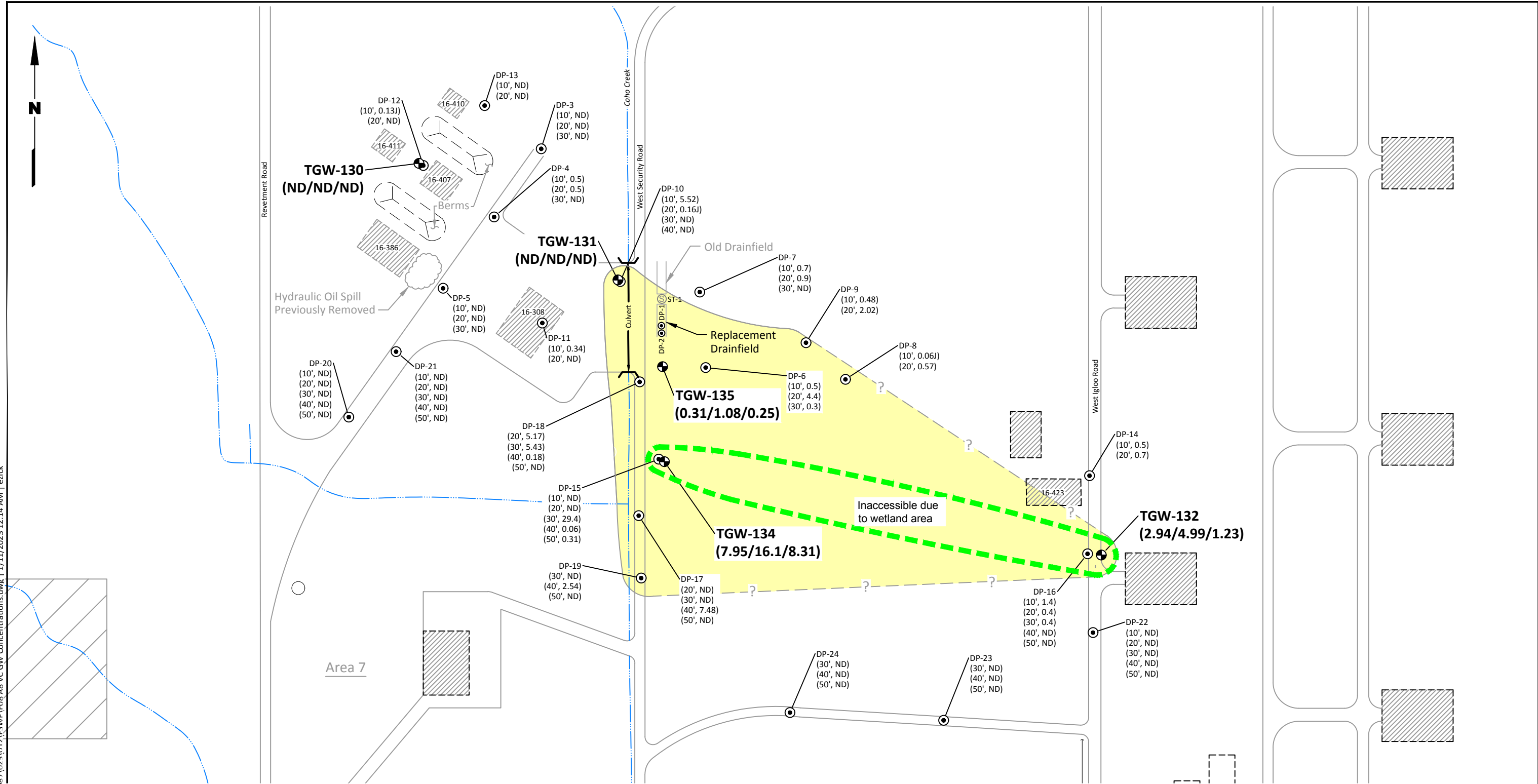
Notes

- New monitoring wells are shown in **bold**.
- Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Base Map Source: Survey map by Duane Hartman and Associates, Inc.



Landau Associates | G:\Projects\025\087\02\3\012\FS\WPI\F08 A8 VC GW Concentrations.dwg | 1/11/2023 12:14 AM | ezick



Building Descriptions

16-308	Control House
16-386	Test Pad
16-407	Ordnance Preparation
16-410	Fuel Test
16-411	Vibration Tables
16-423	Air Compressor Facility

Legend

	Monitoring Well Location
	Most Recent / Maximum / Minimum VC Concentrations (µg/L) in Groundwater Collected from Monitoring Wells through July 2022 Unless Otherwise Noted.
	Direct-Push Probe Groundwater Sampling Location
	Groundwater Sample Depth (ft, bgs) and VC Concentration (µg/L) in Groundwater Samples Collected from Direct-Push Borings July 2017 through June 2018 Unless Otherwise Noted.
	Not Detected

	Septic Tank
	Approximate Coho Creek and Tributary Centerline
	Area where VC is currently detected above 2 µg/L (based on most recent concentrations from monitoring wells sampled in 2022)
	Former Building
	Area where VC has been detected above 2 µg/L (based on maximum concentrations detected)

Note

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

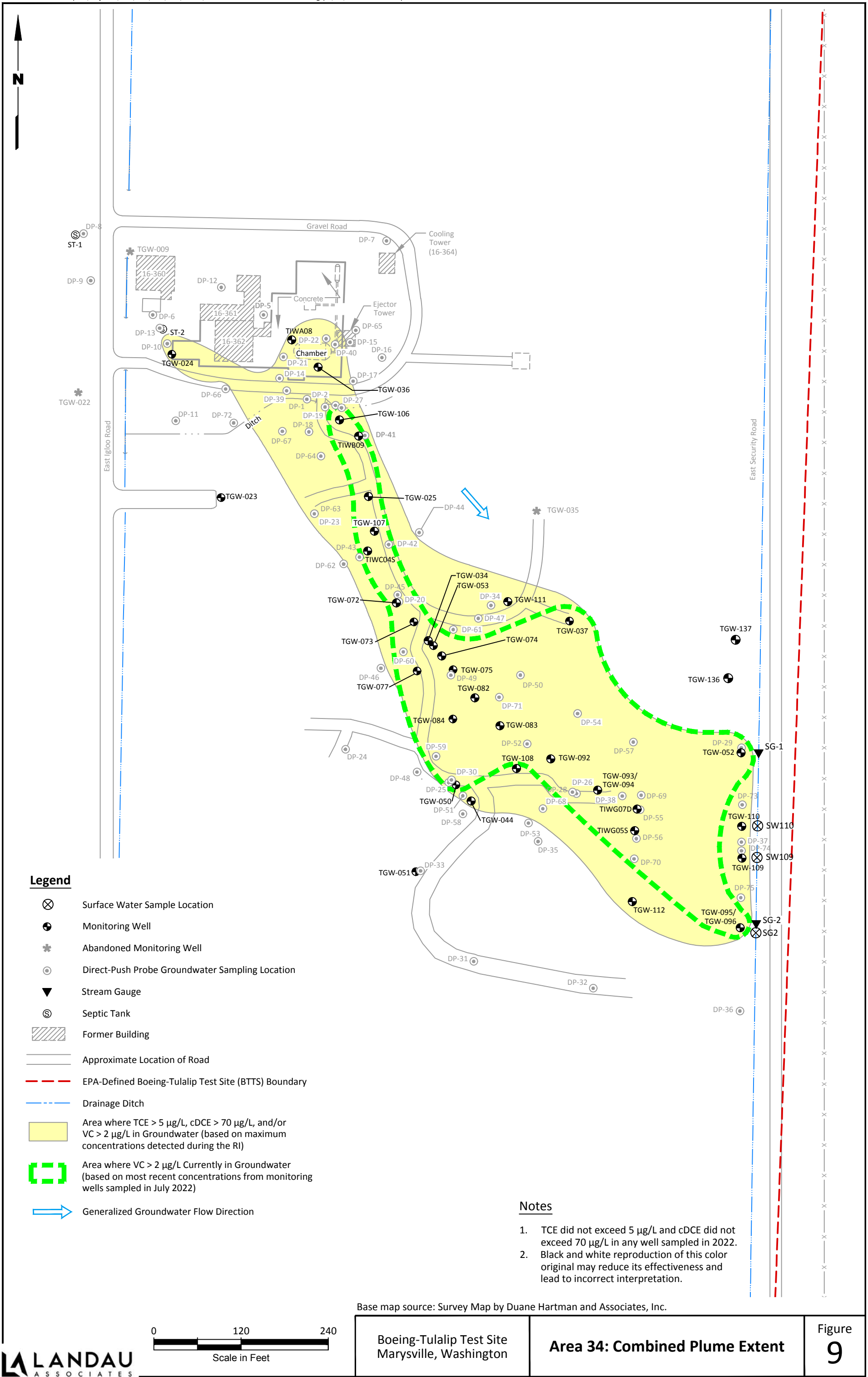
Base map source: Golder Associates 1998



Boeing-Tulalip Test Site
Marysville, Washington

Area 8: VC Groundwater
Concentrations

Figure
8



G:\Projects\025\087\023\012\FSWP\F10A A41 TCE West.mxd 1/11/2023



Legend

- Direct-Push Groundwater Sample Location
- Monitoring Well
- Revised Boeing-Tulalip Test Site (BTTS) Boundary
- BTTS Lease Boundary
- Area where TCE has been detected above 5 µg/L (based on maximum concentrations detected during the RI)
- Area where TCE > 5 µg/L currently in groundwater (based on most recent concentrations (as of January 2022) from monitoring wells and Data Gaps direct-push borings)
- Former Building / Test Pad

ND Not detected

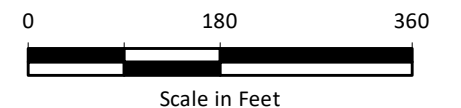
20' = 4.8 Groundwater Sample Depth (ft, bgs) and TCE Concentration (µg/L) in Groundwater Samples Collected from Direct-Push Borings

(103/109/106) Most Recent / Maximum / Minimum TCE Concentrations (µg/L) in Groundwater Collected from Monitoring Wells through July 2022 Unless Otherwise Noted

Notes

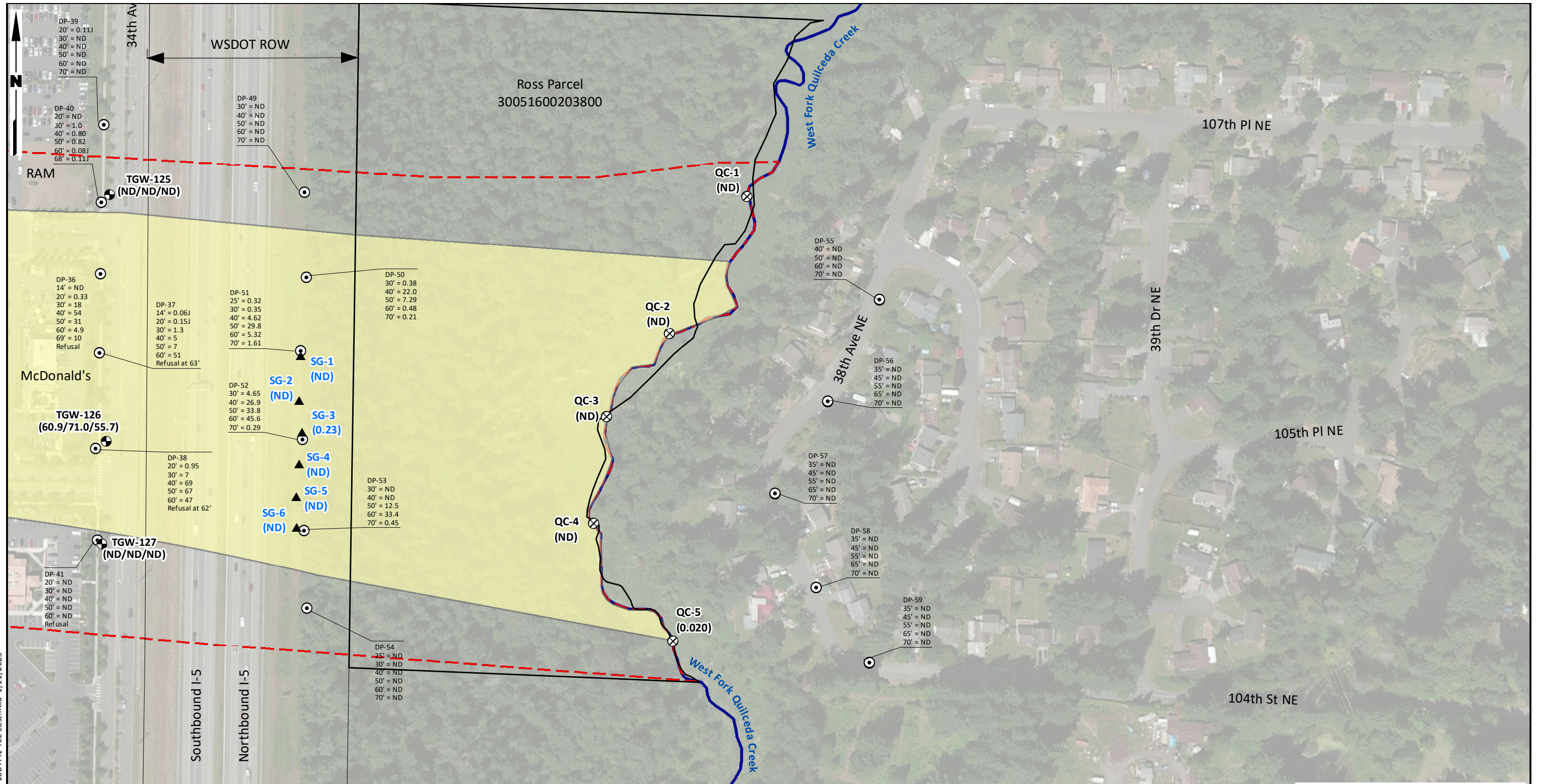
- TCE breakdown products cDCE and VC are not detected above MCLs.
- Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Sources: The Boeing Company; Burlington Environmental, Inc. 1991; Shannon & Wilson 1987; Imagery Google Earth 2017



Scale in Feet

G:\Projects\025\087\023\012\FSWP\F10B A41 TCE East.mxd 1/11/2023



Legend

- SG-1 (ND) ▲ Soil Gas Sample
QC-1 (ND) ⊗ Surface Water Sample
DP-41 (ND) ○ Data Gaps Direct-Push Groundwater Sample
TGW-126 (55.7) ● Monitoring Well

(103/109/106) Most Recent / Maximum / Minimum TCE Concentrations (µg/L) in Groundwater Collected from Monitoring Wells through July 2022 Unless Otherwise Noted

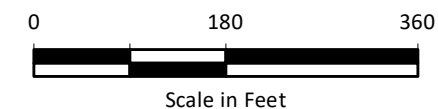
- EPA-Defined Boeing Tulalip Test Site (BTTS) Boundary

Area where TCE has been detected above 5 µg/L (based on maximum concentrations detected during the RI)

Area where TCE > 5 µg/L currently in groundwater (based on most recent concentrations (as of January 2022) from monitoring wells and Data Gaps direct-push borings)

20' = 4.8 Groundwater Sample Depth (ft, bgs) and TCE Concentration (µg/L) in Groundwater Samples Collected from Direct-Push Borings

ND Not detected
TCE in all water samples in µg/L



Sources: The Boeing Company; Burlington Environmental, Inc. 1991; Shannon & Wilson 1987; Esri World Imagery

Notes

1. TCE breakdown products cDCE and VC are not detected above MCLs.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Boeing-Tulalip Test Site
Marysville, Washington

**Area 41: TCE Concentrations in
Groundwater East of I-5**

Figure
10B

Landau Associates | G:\Projects\025\087\023\012\FSWP\F11 Administration Area TCE GW.dwg | 1/11/2023 12:00 AM | ezick

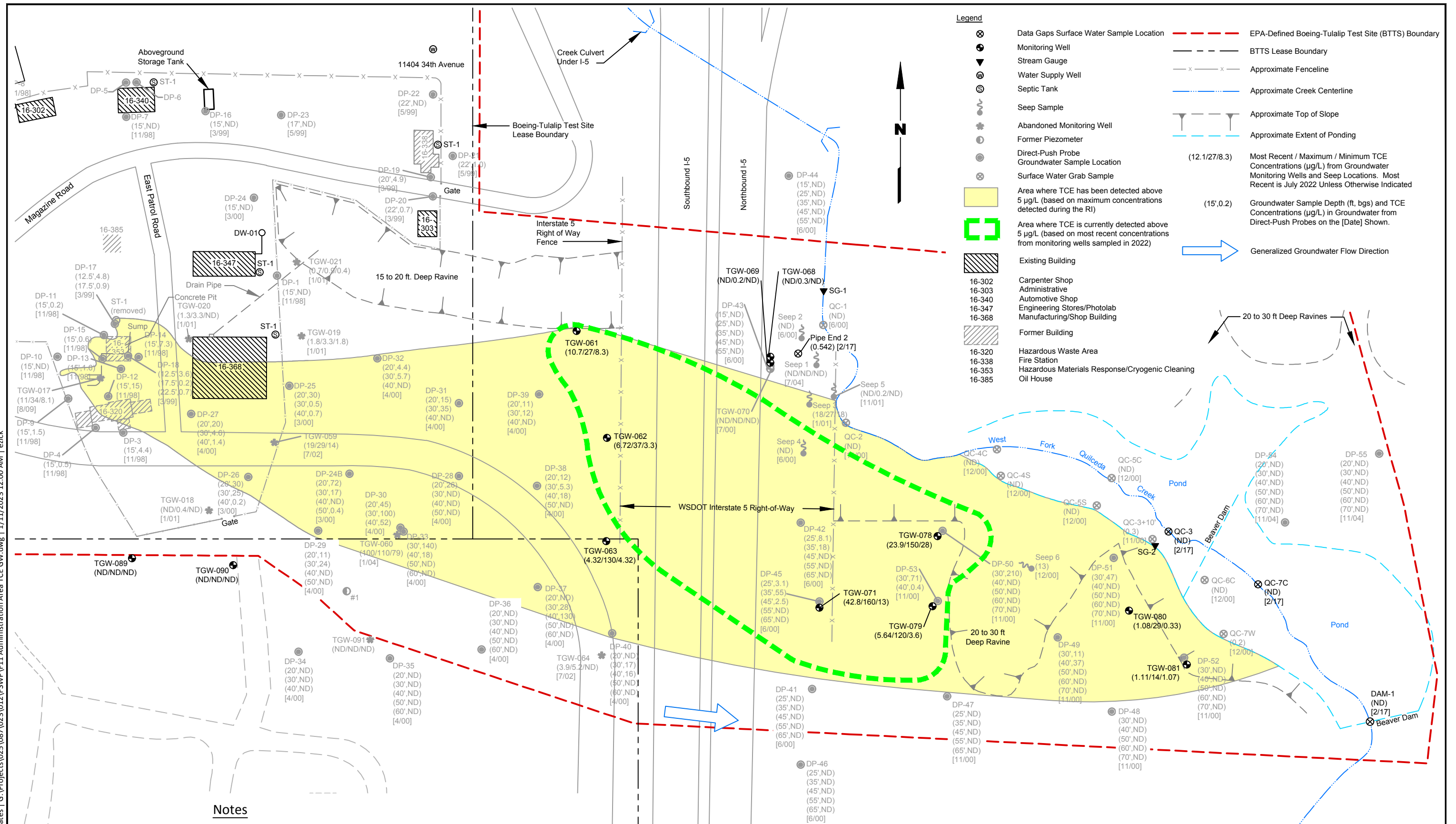


Table 1
Test Areas Summary
Former Boeing-Tulalip Test Site
Marysville, Washington

Test Area	Site Use History	Interim Remedial Actions	RI Investigations Completed (1998 to 2009)	Data Gaps Investigations Completed (2017 to 2020)	Proposed Action(s)
Area 1 Air Blast Simulation Area	General test area; structural and mechanical testing of aircraft components using shock tubes, model rocket test firings, stage separation tests; concrete pad, control house, septic tank.	- Septic tank pumped and cleaned. - Excavation of approximately 15 yd ³ of hydraulic oil-impacted soil.	Soil, groundwater, and septic tank (sludge and water).	Groundwater.	Evaluation of groundwater plume in the FS.
Area 2 Minute Man Missile Silo Mock-Up Area	Mock-ups of missile silos were used to test anti-intrusion security systems that used radar to sense movement; and a “Torus Simulator” used for electromagnetic pulse testing.	None.	None. The Parcel 3 environmental assessment (Boeing 1992) concluded environmental conditions did not exist that would affect termination of the lease.	None.	None.
Area 4 Propellant Manufacture and Bird Strike Area	Bird impact testing for windshield certification, solid propellant manufacturing, machining, and TNT melting and casing; three buildings, floor drain, drain field.	None.	Soil and groundwater.	None.	Groundwater evaluated as part of Area 5 plume.
Area 5 Liquid Hydrogen Test Area	Testing of small rockets fueled by both solid and liquid propellants. Three buildings, berms to separate two testing areas. Two-tank pumped septic system, raised mound drain field.	- Dual septic tanks pumped and cleaned.	Soil, groundwater, surface water, and septic tank (sludge and water).	Groundwater and surface water.	Evaluation of groundwater plume in the FS.
Area 7 Propellant Oxidizer Storage Area	Used for storing fluorine gas and nitrogen tetroxide (the latter, an oxidizer for the rocket engine tests at Area 34; covered concrete pad).	None.	None.	None.	None.
Area 8 Missile System Tank Area and five buildings (Bldgs #308, 407, 411, 410, and 386)	Testing of Peacekeeper seals, engine shaking, propellant expulsion, space shuttle heat sink tanks, thermal meteoroid protection, propellant extinguisher systems, cryogenics, solid propellants, and ordnance preparation; five buildings, one septic, two drain fields.	- Septic tank pumped and cleaned.	Groundwater and septic tank (sludge and water).	Groundwater.	Evaluation of groundwater plume in the FS.
Area 9 Hover Test Area	Constructed in 1995 for air dynamics testing; air craft test stand, concrete pads for ASTs.	- Excavation of approximately 9 yd ³ of petroleum-contaminated soil.	Soil and groundwater.	None.	Groundwater evaluated as part of Area 5 plume.
Area 14 Jet Engine Test Area	Used for jet engine testing; two engine stands, concrete igloo (control house), building connected to septic system, drain field; two USTs removed in 1990.	1998: Removal of 1,200 ft of petroleum pipelines and approximately 1,230 yd ³ of petroleum-contaminated soil excavated. Pumped out and cleaned septic tank.	Soil, groundwater, and septic tank (sludge and water).	Groundwater.	None.
Area 29 Impact Fuse Test Area	Consisted of a 300-ft long, dead-end gravel road with a metal target plate at the base of a hillside; used for firing non-exploding rounds at the target from a military tank located on the access road. Dummy rounds passed through a steel pipe welded at the center of the target, and lodged into the hillside behind it.	Approximately 200 yd ³ of metals-contaminated soil excavated.	Soil and debris.	Soil.	None.

Table 1
Test Areas Summary
Former Boeing-Tulalip Test Site
Marysville, Washington

Test Area	Site Use History	Interim Remedial Actions	RI Investigations Completed (1998 to 2009)	Data Gaps Investigations Completed (2017 to 2020)	Proposed Action(s)
Area 31 Explosives Test Area	Used for a variety of different testing purposes including bird impact testing for windshield certification, gunfire tests for helicopter blades, aircraft windows, and armor. Missile silo pop up tests, explosives forming, ordnance detonation, and gas cylinder venting/destruction activities also occurred at a below-grade steel-lined pit known as an explosive forming pit. File review did not identify any specific release or spill of hazardous materials.	1999: Approximately 10 yd ³ of petroleum-contaminated soil excavated.	Soil and groundwater.	None.	None.
Area 34 High-Altitude Test Facility	Used for simulating high altitude and high temperature testing of small rocket engines; laser testing; three buildings and a number of other structures, two septic tanks and drain fields, one diesel UST.	1993: Diesel UST removed. 1998 and 1999: - 10,000-gallon UST removed and 100 yd ³ of petroleum-impacted soil excavated - 33 yd ³ of petroleum-contaminated soil removed near the northwest corner of former Bldg 16-360 - Septic tanks pumped out and removed. - 40 yd ³ of metals-impacted soils removed from ditch. - 90 yd ³ of soil removed containing hydrazines near the former vacuum chamber. - 33 yd ³ of soil removed containing arsenic from East Igloo Road.	Soil, groundwater, surface water, and septic tank (sludge and water),	Soil and surface water.	Evaluation of groundwater plume in the FS.
Area 41 Cryogenic Structural Test Facility	Creep, static, and fatigue load testing of materials under cryogenic and elevated temps; control house/shop, three test pads, and liquid hydrogen storage.	Excavation of 6 yd ³ of soil impacted by hydraulic fluid. Excavation of 100 yd ³ of soil impacted by heat transfer fluid.	Soil and groundwater.	Groundwater, surface water, and soil gas.	Evaluation of groundwater plume in the FS.
Area 43 Burn Trenches	Used for Peacekeeper missile deployment tests and burn area for ordnance, packing material, and other debris.	Excavation of approximately 100 yd ³ of debris and contaminated soil.	Soil and groundwater.	Soil and groundwater.	None.
Former Burn Area	Used for burning and/or burial of various debris.	1999: Excavation of approximately 1,100 yd ³ of soil and debris.	Soil and groundwater.	None.	None.

Table 1
Test Areas Summary
Former Boeing-Tulalip Test Site
Marysville, Washington

Test Area	Site Use History	Interim Remedial Actions	RI Investigations Completed (1998 to 2009)	Data Gaps Investigations Completed (2017 to 2020)	Proposed Action(s)
Administration Area	Nine buildings for various support activities. TCE degreaser in Bldg 16-353. Five septic tanks.	1998 and 1999: - Excavation of approximately 6 yd ³ of soil at Bldg 16-302. - Excavation of approximately 6 yd ³ of soil west of Bldg 16-347. - Excavation of approximately 50 yd ³ of soil from west side of Bldg 16-368. - Bldg 16-347 and former Bldg 16-353 septic tanks excavated and removed. - Three other septic tanks were pumped and cleaned. 2009: Excavation of 2,200 tons of PCB- and TCE-contaminated soil and debris excavated. PCBs not detected in groundwater.	Soil, soil vapor, groundwater, surface water, seep, and septic tank (sludge and water).	Groundwater and surface water.	Evaluation of groundwater plume in the FS.
Igloo 26	Used to store equipment related to testing at Bldg 16-420; two-tank pumped septic system and raised mound drain field.	Pumped out and cleaned septic tanks.	Septic tank (water; no sludge present).	None.	None.
Building 16-420 Impact Mechanics Facility	Used for impact and ballistics tests and for missile manufacturing; septic tank.	Septic tank pumped out and removed.	Soil, groundwater, and septic tank (sludge and water).	Groundwater.	None.
Building 16-423 Air Compressor Facility	Air compressor; building sump.	Excavation of approximately 12 yd ³ of soil.	Soil.	None.	None.
Helipad (south of Administration Area)	Although available site documents do not provide detail on activities at the helipad, it is considered highly unlikely that refueling or maintenance would have been performed at this remote location instead of at nearby Boeing Field or other nearby airfield locations.	None	None. The Parcel 3 environmental assessment (Boeing 1992) concluded environmental conditions did not exist that would affect termination of the lease.	None	None
Other - Roadway	Possible oiling of site roads.	None	None	Soil	

Abbreviations and Acronyms:

AST = aboveground storage tank
Bldg = Building
FS = feasibility study
ft = feet
PCB = polychlorinated biphenyl
RI = remedial investigation
TCE = trichloroethene
TNT = trinitrotoluene
UST = underground storage tank
yd³ = cubic yards

Reference:

Boeing. 1992. Tulalip Test Facility Parcel 3, Marysville, Washington, Lease Termination Environmental Assessment. The Boeing Company. August 17.

Table 2
Groundwater Plume Summary
Former Boeing-Tulalip Test Site
Marysville, Washington

Test Area	General Description	Primary Sources (a)	Plume Area, COCs, and Depth	Redox State	Pilot Testing/Treatability Testing
Area 1 Air Blast Simulation Area	TCE plume extending east from a former concrete test pad toward 27th Avenue.	Non-point source releases to the ground.	Initial 5-acre TCE plume naturally attenuated to 4.2 acres; cDCE also present. Extends approx. 1,200 ft downgradient and maximum width of approx. 300 ft, maximum depth is approx. 30 ft bgs.	Naturally aerobic with minor cDCE production occurring in siltier layers/lenses having iron-reducing redox.	None.
Area 5 Liquid Hydrogen Test Area	TCE plume and smaller area cDCE and VC plumes extending from former test area beneath Coho Creek and West Security Road.	Non-point source releases to the ground.	Initial 7.4-acre TCE plume naturally attenuated to 5.2 acres; cDCE present under natural conditions; 1.6-acre VC plume resulting from bioremediation pilot testing. TCE plume extends approx. 900 ft downgradient. The 800-ft VC plume extends from pilot test area to approximately 300 ft beyond the TCE plume. Plumes start relatively shallow (less than 30 ft bgs) and extend deeper (60 to 90 ft bgs) with distance downgradient.	Naturally anaerobic and iron-reducing, as indicated by substantial cDCE production. VC and associated sulfate-reducing conditions resulted from bioremediation pilot testing.	Bioremediation pilot testing.
Area 8 Missile System Tank Area and five buildings (Bldgs #308, 407, 411, 410, and 386)	VC plume originating near former Bldg 16-407 and extending beneath Coho Creek and West Security Road.	Non-point source releases to the ground.	Initial 5.4-acre VC plume naturally attenuated to 1.15 acres. cDCE also present. Parent product TCE detected infrequently at less than 1 µg/L. Extends approx. 1,200-ft downgradient.	Naturally anaerobic and sulfate-reducing to methanogenic, as indicated by TCE degradation to VC and VC attenuation over time.	None.
Area 34 High-Altitude Test Facility	TCE and cDCE plumes extending from former test area to East Security Road.	Non-point source releases to the ground; release from septic system.	Initial TCE and cDCE combined plume (cDCE present under natural conditions) of 3.5 acres was fully degraded to VC and non-toxic end products ethene/ethane during bioremediation treatability testing. The 2.9-acre VC plume remaining at the end of testing shows further degradation to ethene/ethane and VC concentrations decreasing over time.	Naturally anaerobic and iron-reducing, as indicated by substantial cDCE production. Further degradation to VC and ethene/ethane and associated sulfate-reducing to methanogenic conditions resulted from bioremediation treatability testing.	Bioremediation pilot and treatability testing.
Area 41 Cryogenic Structural Test Facility	TCE plume extending from former test area beneath I-5 ROW to the WFQC.	Non-point source releases to the ground.	42-acre TCE plume. cDCE present at less than 10 µg/L. VC detected infrequently at less than 0.1 µg/L. Plume extends approx. 3,200-ft downgradient. 600-ft wide. Depth from 10 to 70 ft bgs.	Naturally aerobic with minor cDCE production occurring in siltier layers having iron-reducing redox.	None.
Administration Area	TCE plume originating near former Bldg 16-353 and extending beneath the I-5 ROW to the WFQC.	Non-point source releases to the ground; releases from septic system and an industrial drain field; possibly from AST and/or degreaser at former Bldg 16-353.	Initial 15-acre TCE plume naturally attenuated to 5.1 acres. cDCE and VC detected in a single well where natural peat deposit occurs. Plume extends approx. 2,000-ft downgradient. 500-ft wide. Depth 15 to 60 ft bgs.	Naturally aerobic, with cDCE and VC production occurring in isolated peaty area (one monitoring well) near the WFQC.	None.

Table 2
Groundwater Plume Summary
Former Boeing-Tulalip Test Site
Marysville, Washington

Notes:

(a) As documented in the RI, high-strength, dense non-aqueous phase liquid (DNAPL) sources do not exist at any of the release areas for cVOC plumes at the site. Maximum TCE groundwater concentrations are less than 100 µg/L near the head of the plumes, much lower than would occur with a DNAPL source. Furthermore, the highest concentrations of TCE in groundwater plumes occur substantially downgradient from suspected release areas. This concentration distribution suggests that plumes are the result of historical aqueous-phase releases (i.e., not DNAPL releases), with the highest concentrations having migrated downgradient over time as a slug of aqueous-phase contamination. This is in contrast to a DNAPL release, which would be indicated by a persistent source in the release area with much higher TCE concentrations than detected in the downgradient plume.

Abbreviations and Acronyms:

- µg/L = micrograms per liter
- AST = aboveground storage tank
- bgs = below ground surface
- Bldg = Building
- cDCE = cis-1,2-dichloroethene
- COC = chemical of concern
- cVOC = chlorinated volatile organic compound
- ft = feet
- I-5 = Interstate 5
- RI = remedial investigation
- ROW = right of way
- TCE = trichloroethene
- VC = vinyl chloride
- WFQC = West Fork Quilceda Creek

Table 3
Applicable or Relevant and Appropriate Requirements
Former Boeing-Tulalip Test Site
Marysville, Washington

ARARs	Source	Type of ARAR (a)	Description/Rationale
Federal			
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP)	42 USC 9601 40 CFR 300	C, A	Applicable. FS report must be prepared in accordance with CERCLA RI/FS guidance.
Resource Conservation and Recovery Act (RCRA)	42 USC 6901 40 CFR 239 - 282	C, A	If wastes are generated or stored onsite as part of remedial actions that meet the definition of hazardous waste, then the RCRA hazardous waste regulations may be applicable to the management of those wastes.
Maximum Contaminant Levels (MCLs)	40 CFR 141	C	MCLs regulate concentration of contaminants in public drinking water supplies but may also be considered for groundwater aquifers used for drinking water.
Maximum Contaminant Level Goals (MCLGs)	40 CFR 141	C	MCLGs are health-based criteria that should be evaluated for groundwater contamination.
Clean Water Act, Ambient Water Quality Criteria (AWQC)	40 CFR 131	C	Establishes Federal AWQC for restoration and maintenance of chemical, physical, and biological integrity of the nation's surface waters. May be relevant to remedial actions impacting contaminant migration to surface water.
Regional Screening Levels for Chemical Contaminants at Superfund Sites	https://www.epa.gov/risk/regional-screening-levels-rsls	C	Establishes regional chemical screening levels to be used in risk assessments. May be considered in development of cleanup goals.
Vapor Intrusion Screening Levels	https://www.epa.gov/vaporintrusion/vapor-intrusion-screening-level-calculator	C	Establishes screening levels for groundwater, soil gas and indoor air for protection of indoor air from vapor intrusion. May be considered in development of cleanup goals.
Wetlands, floodplains, fish, and wildlife; endangered species	40 CFR 6.302 16 USC 1531	L	To be considered in selection of final site remedial alternative. May be applicable if wetlands and/or endangered species are identified at the site.
Federal Protection of Wetlands	Executive Order 11990; 40 CFR 6, Appendix A	L	To be considered in selection of final site remedial alternative.
National Historical Preservation Act	16 USC 470	L	May be applicable if materials found during cleanup activities.
Occupational Safety and Health Act (OSHA)	29 USC 651; 29 CFR 1910, 1926	A	Applicable to remedial site activities.
EPA Underground Injection Control (UIC) Program Regulations	40 CFR 144 and 146	A	Regulated injections into underground sources of drinking water by specific classes of injection wells. Relevant to any <i>in situ</i> remediation technologies that involve injection.
Transportation of Hazardous Wastes	49 CFR 171	A	Federal Highway Administration, Department of Transportation National Highway Traffic Safety Administration regulations are codified in 23 CFR Parts 1-1399. Applicable to remedial activities that involve the off-site transportation of hazardous waste.
Clean Water Act and NPDES Requirements	40 CFR 122 and 125	A	Regulates discharge of pollutants into navigable waters. Substantive requirements will be applicable to any alternative that discharges effluent to surface water.
State			
Model Toxics Control Act (MTCA)	WAC 173-340	C	Establishes administrative processes and standards in Washington State to identify, investigate, and clean up facilities where hazardous substances have come to be located.
Washington State Maximum Contaminant Levels in Drinking Water	WAC 246-290-300	C	Establishes maximum contaminant levels allowed in public drinking water systems in Washington State.
Cultural Resource Review	Executive Order 21-02	L	Cleanup activities requiring substantial excavation would potentially require review by the Washington State Department of Archaeology and Historic Preservation and/or by the Tribes.
Washington Hazardous Waste Management Act and implementing regulations: Dangerous Waste Regulations	RCW 70A.300; WAC 173-303	A	These regulations establish a comprehensive statewide framework for the planning, regulation, control, and management of dangerous waste. The regulations designate those solid wastes that are dangerous or extremely hazardous to human health and the environment. The management of excavated contaminated soil from the site would be conducted in accordance with these regulations to the extent that any dangerous wastes are discovered or generated during the cleanup action.
Washington Solid Waste Management Act and its implementing regulation: Criteria for Municipal Solid Waste Landfills	RCW 70A.205; WAC 173-351	A	These regulations establish a comprehensive statewide program for solid waste management including proper handling and disposal. The management of any contaminated soil removed from the site would be conducted in accordance with these regulations to the extent that this soil could be managed as solid waste instead of dangerous waste.

Table 3
Applicable or Relevant and Appropriate Requirements
Former Boeing-Tulalip Test Site
Marysville, Washington

ARARs	Source	Type of ARAR (a)	Description/Rationale
Hazardous Waste Operations	WAC 296-843	A	Establishes safety requirements for workers conducting investigation and cleanup operations at sites containing hazardous materials. These requirements would be applicable to onsite cleanup activities and would be addressed in a site health and safety plan prepared specifically for these activities.
State Construction Stormwater General Permit	WAC 173-220	A	Construction activities that disturb one or more acres of land would typically need to obtain an NPDES Construction Stormwater General Permit from Ecology. A substantive requirement would be to prepare a SWPPP prior to earthwork activities. The SWPPP would document planned procedures designed to prevent stormwater pollution by controlling erosion of exposed soil and by containing soil stockpiles and other materials that could contribute pollutants to stormwater.
Clean Water Act, Section 401, Water Quality Certification	WAC 173-225	A	Section 401 of the Federal Water Pollution Control Act provides that applicants for a license or permit from the federal government relating to any activity that may result in any discharge into the navigable waters shall obtain a certification from the state that the water quality standards will be met. Ecology’s Water Quality Section would review any Nationwide Permit No. 38 issued by the US Army Corps of Engineers. Ecology would also review any associated draft and final design of the chosen cleanup action alternative to document substantive compliance with the Washington State Water Pollution Control Act requirements.
State Environmental Policy Act (SEPA)	RCW 43.21C; WAC 197-11	A	SEPA checklist may be required to determine if the alternatives selected as part of the FS for cleanup have an environmental impact. Under the SEPA rules, MTCA and SEPA processes are to be combined to reduce duplication and improve public participation (WAC 97-11-250). Ecology is the lead agency for implementing the substantive requirements of SEPA as described in WAC 197-11-253.
Washington Minimum Standards for Construction and Decommissioning	WAC 173-160-381	A	Ecology or its delegated authority establishes requirements for the installation and decommissioning of monitoring wells.
Electrical Equipment Installations	RCW 19.28	A	Electrical wiring and equipment may be needed to power active controls and blower motors for SVE and DGR treatments.
Underground Injection Control (UIC) Program	WAC 173-218	A	UIC registration would be required for the injection of any materials below ground surface for the purposes of groundwater cleanup. This would include injection of reducing agents such as zero-valent iron, electron donor substrates for bioremediation, oxidants for chemical oxidation, or other chemical activation agents or catalysts; or reinjection of treated groundwater.
Uniform Environmental Covenants Act	RCW 64.70	A	Regulation that addresses recording environmental covenant as element of the final remedy selected.
Tribal			
Tribal Drinking Water Standards	Tulalip Tribes Department of Environment 1995	C	Applicable regulation for drinking water standards (matches Federal MCLs)
Tribal Comprehensive Land Use Plan	Tulalip Tribes 2009	L, A	Cleanup activities should meet tribal environmental protection goals and not interfere with plans for future land use and redevelopment of the site.

Notes:
a) A = action-specific ARAR; C = chemical specific ARAR; L = Location specific ARAR
Tribal Reservations are not subject to Washington State regulations. However, state regulations may be considered in the development of cleanup and remedial action levels.

Abbreviations and Acronyms:

ARARs = applicable or relevant and appropriate requirements
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CFR = Code of Federal Regulations
DGR = dynamic groundwater recirculation
Ecology = Washington State Department of Ecology
EPA = Environmental Protection Agency
FS = feasibility study
MCL = maximum contaminant levels
MCLG = maximum contaminant level goal
MTCA = Model Toxics Control Act
NCP = National Contingency Plan
NPDES = National Pollutant Discharge Elimination System

OSHA = Occupational Safety and Health Act
RCRA = Resource Conservation and Recovery Act
RCW = Revised Code of Washington
RI = remedial investigation
SEPA = State Environmental Policy Act
SVE = soil vapor extraction
SWPPP = stormwater pollution prevention plan
Tribes = Tulalip Tribes
UIC = underground injection control
USC = United States Code
WAC = Washington Administrative Code

References:

Tulalip Tribes. 1995. Tulalip Tribes Final Water Quality Standards. Tulalip Tribes Department of Environment.
Tulalip Tribes. 2009. Comprehensive Land Use Plan. Tulalip Tribes Community Development Department and the Tulalip Tribes Planning Commission. <https://www.tulaliptribes-nsn.gov/Base/File/TTT-PDF-2009-Comprehensive-Land-Use-Plan-09162021>. September.

Table 4
Preliminary Remediation Goals - Groundwater
Former Boeing-Tulalip Test Site
Marysville, Washington

Analyte	Risk-Based Exposure Pathways					ARARs			PRG (µg/L)	Basis
	Groundwater Protective of Dermal and Incidental Ingestion - Construction Worker (µg/L)		Groundwater Protective of Drinking Water - Commercial Worker (µg/L)		Groundwater Protective of Indoor Air - Commercial	Federal MCLs (µg/L)	Washington State MCL (µg/L)	Tribal Drinking Water Standard (µg/L)		
	Cancer ⁽¹⁾	Non-Cancer ⁽²⁾	Cancer ⁽¹⁾	Non-Cancer ⁽²⁾						
Trichloroethene	5,060	166	36	29	14	5	5	5	5	MCL
cis-1,2-Dichloroethene	--	7,037	--	117	--	70	70	70	70	MCL
Vinyl Chloride	400	1,232	2.3	175	3.5	2	2	2	2	MCL

Notes:

(1) Cancer values are based on a target cancer risk of 10⁻⁵.

(2) Non-cancer values are based on a target hazard quotient of 1.

Abbreviations and Acronyms:

µg/L = micrograms per liter

ARAR = applicable or relevant and appropriate requirement

MCL = maximum contaminant level

PRG = preliminary remediation goal

Table 5
Action Levels and PRGs for Protection of Commercial Indoor Air
Former Boeing-Tulalip Test Site
Marysville, Washington

Analyte	Action Level		PRG
	Groundwater Protective of Indoor Air ⁽¹⁾ (µg/L)	Soil Gas Protective of Indoor Air (µg/m ³)	Indoor Air (µg/m ³)
TCE	14	100	3
VC	3.5	93	2.8

Notes:

(1) Applies to groundwater at the shallowest groundwater interval (at the water table).

Assumptions: Default commercial exposure scenarios, target cancer risk level of 10⁻⁶, target hazard quotient of 1 for potential non-cancer effects, and groundwater temperature of 11 degrees Celsius.

Source: EPA. 2020. Vapor Intrusion Screening Level (VISL) Calculator. US Environmental Protection Agency.
https://epa-visl.ornl.gov/cgi-bin/visl_search. July 24.

Abbreviations and Acronyms:

µg/L = micrograms per liter

µg/m³ = micrograms per cubic meter

PRG = preliminary remediation goal

TCE = trichloroethene

VC = vinyl chloride

Table 6A
Screening of Technologies and Process Options Applicable to Soil Vapor
Former Boeing-Tulalip Test Site
Marysville, Washington

General Response Action	Technology Type	Process Option	Description	General Benefits/Limitations	Effectiveness	Implementability	Cost	Screening Comments	Screening Result Retain/Reject
No Action	No Action	No Action	Included in Remedial Alternatives as required by CERCLA guidance.	Benefits: Low cost and easy to implement. Limitations: Does not achieve RAOs.	Not Effective Required for consideration as a baseline for comparison.	Easy	None	Included as a Remedial Alternative as required by CERCLA guidance.	Retain
Institutional Controls/ Engineering Controls	Institutional Controls	Restrictive Environmental Covenant, Signage, Access Agreements	Limits use/access to contaminated media. Access agreement required for treatment, as Boeing does not own the site.	Benefits: Low cost. Restricts use of/exposure to contaminated media. Requires engineering controls or signage. Limitations: Does not provide treatment.	Moderate Effective at preventing exposure, but does not reduce contaminant mass or concentrations. Can be combined with other technologies to make more protective. Requires signage, may require engineering and/or access controls (e.g., fencing, capping).	Easy Restrictive environmental covenants and other institutional controls can be readily implemented.	Capital: Low Long-Term (OMM): Low Overall: Low	Potentially applicable: Effective at reducing potential exposure pathways.	Retain
		Vapor Barrier	Prevent vapor intrusion to new buildings through emplacement of impermeable barrier during construction of building footings and slab/crawl space.	Benefits: Provide protection of the vapor intrusion pathway. Limitations: Feasible only for new construction.	High Properly constructed, vapor barriers will eliminate vapor intrusion.	Easy Simple addition sub-slab/foundation membrane or sealants for new construction.	Capital: Low Long-Term (OMM): Low Overall: Low	Potentially applicable: For new buildings that may be constructed in the future over or near VOC plumes, where vapor intrusion risk is determined to be a concern.	Retain
	Vapor Intrusion Engineering Controls	Sub-Slab Depressurization (SSD)	System installed in buildings with concrete floors. Low-flow blower maintains negative pressure beneath the building to prevent vapor intrusion. Blower effluent routed outside the building, generally without vapor treatment.	Benefits: Provide protection of the vapor intrusion pathway. Limitations: Does not provide direct treatment of cVOCs. Must operate continuously to be effective and will require operation for a long period of time to meet screening levels.	High Technology is well-documented for protection of indoor air.	Moderate Requires SSD wells or sumps with vacuum conveyance lines, blower system, and discharge.	Capital: Low to Moderate Long-Term (OMM): Moderate Overall: Moderate	Not applicable: Technology is more applicable to existing buildings and less practical than vapor barriers for new construction. No existing buildings with vapor intrusion concerns (a).	Reject
Soil Vapor Extraction (SVE)				Benefits: Effective at extracting soil vapor from vadose zone causing continual flushing and removal of cVOCs in soil vapor. Limitations: Does not provide direct treatment of cVOCs in saturated zone. Preferential flow paths or silty zones may limit complete cleanup of impacted vadose soil. Challenging at sites with shallow water table (i.e., small vadose zone thickness) which requires tighter well spacing and potentially an impermeable barrier over the treatment zone to develop vacuum influence.	Moderate Technology is well-documented for treating cVOCs. Effective for treatment of soil and soil gas. Can be implemented to prevent soil vapor intrusion. SVE would be challenging at site plumes with shallow water table (i.e., small vadose zone thickness).	Low to Moderate Requires SVE wells with power and conveyance lines, treatment system, and permitted discharge. Shallow water table would result in need for high density of vertical or horizontal SVE wells, and potentially make implementation infeasible.	Capital: Moderate Long-Term (OMM): Moderate Overall: Moderate	Not applicable: Not applicable for plume areas due to most plume areas with less than 10 ft of vadose zone.	Reject
<i>In Situ</i> Treatment	Physical/ Chemical	Thermal Treatment	Removal of volatile contaminants through <i>in situ</i> heating (e.g., electrical resistance heating [ERH] or thermal conduction heating [TCH]) of vadose zones.	Benefits: Removal of contaminants through heating to increase vapor COC pressure and volatilization rate. Treatment can be designed to treat both high- and low-permeability zones. Residual heat after active heating can temporarily enhance natural attenuation/bioremediation. Cleanup can be achieved in very short restoration time frame. Low temperature thermal can also increase biotic and abiotic remediation rates over longer time frames. Limitations: Energy-intensive, typically used in high-concentration source zones, not for downgradient plumes. Requires extensive belowground and aboveground infrastructure. Safety concerns within treatment area, especially where belowground conductive infrastructure (e.g., piping) extend aboveground.	High Established technology for cVOCs. Highly effective in removing cVOCs from low-permeability matrices.	Difficult No high concentration source zones at the Site. Not applicable to large, diffuse plumes. Requires substantial aboveground and belowground infrastructure (heating wells, vapor recovery wells, power and vapor conveyance lines) and treatment system.	Capital: Very High Long-Term (OMM): Very High Overall: Very High	Not applicable: Technology is cost prohibitive unless treating high concentration source zones including DNAPL. No high concentration source zones are present at the Site.	Reject

Notes:
Green highlighting indicates a technology retained for assembling remedial alternatives in the feasibility study (FS). Remedial alternatives will undergo a detailed evaluation in the FS Report.
(a) Soil vapor and indoor air sampling of the Admin Area shop building demonstrated no unacceptable levels of cVOCs in indoor air. No other occupied buildings exist at the site over cVOC groundwater plumes with cVOC impacts at the water table.

Abbreviations and Acronyms:
Admin = Administration
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
COC = chemical of concern
cVOC = chlorinated volatile organic compound
DNAPL = dense nonaqueous phase liquid
ERH = electrical resistance heating
FS = feasibility study
ft = feet
OMM = operations, maintenance, and management
RAO = remedial action objective
Site = former Boeing-Tulalip Test Site
SSD = sub-slab depressurization
SVE = soil vapor extraction
TCH = thermal conduction heating
VOC = volatile organic compound

Table 6B
Screening of Technologies and Process Options Applicable to Groundwater
Former Boeing-Tulalip Test Site
Marysville, Washington

General Response Action	Technology Type	Process Option	Description	General Benefits/Limitations	Effectiveness	Implementability	Cost	Screening Comments	Screening Result Retain/Reject
No Action	No Action	No Action	Included in Remedial Alternatives as required by CERCLA guidance.	Benefits: Low cost and easy to implement. Limitations: Does not achieve RAOs.	Not Effective Required for consideration as a baseline for comparison.	Easy	None	Included as a Remedial Alternative as required by CERCLA guidance.	Retain
Institutional Controls/ Engineering Controls	Institutional Controls	Restrictive Environmental Covenant, Signage, Access Agreements	Limits use/access to contaminated media. Access agreement required for treatment, as Boeing does not own the Site.	Benefits: Low cost. Restricts use of/exposure to contaminated media. Requires engineering controls or signage. Limitations: Does not provide treatment.	Moderate Effective at preventing exposure, but does not reduce contaminant mass or concentrations. Can be combined with other technologies to make more protective. Requires signage, may require engineering and/or access controls (e.g., fencing, capping).	Easy Restrictive environmental covenants and other institutional controls can be readily implemented.	Capital: Low Long-Term (OMM): Low Overall: Low	Potentially applicable: Effective at reducing potential exposure pathways.	Retain
Natural Attenuation	Monitored Natural Attenuation	Monitored Natural Attenuation	Monitoring of COC concentration reduction due to naturally occurring attenuation processes, including biological and chemical degradation, sorption, and dispersion to confirm stable or shrinking groundwater plumes. Also monitoring of COC concentration reduction in areas with existing and established forested wetland vegetation where attenuation is enhanced by naturally occurring phyto-degradation (monitored phyto-attenuation). Applicable at the Site for plumes that show a decreasing concentration trend under natural conditions and as a polishing phase after active treatment.	Benefits: Natural treatment of entire plumes (both vertical and horizontal extent); includes <i>in situ</i> degradation of contaminants. Phyto-attenuation uses natural transpiration and root zone enzymes to treat shallow groundwater contaminants. Can be used as polishing step following other technologies. Low cost of implementation. Limitations: Variable degradation rates, potentially longer restoration time frame than more active alternatives, which may result in an extended period of ongoing monitoring. Generally follows active source removal or plume treatment. Requires an understanding and demonstration of attenuation processes.	Moderate to High Effectiveness of MNA is dependent on aquifer and contaminant characteristics. Area 1 and Area 5 are naturally anaerobic and conducive to partial reductive dechlorination of TCE to cDCE. Area 8 is naturally anaerobic and conducive to reductive dechlorination of TCE through VC. Area 34 was naturally anaerobic; had treatability testing completed which resulted in complete reductive dechlorination to non-toxic end products. Area 41 and Admin Area are aerobic and little to no breakdown products of TCE are present.	Easy Groundwater cVOCs and MNA parameters can easily be monitored in existing monitoring wells. Can be combined with monitored phyto-attenuation in areas that will remain undeveloped due to wetlands or other limitations (for Area 8, and south portions of Area 34 and Area 1).	Capital: Low Long-Term (OMM): Moderate Overall: Low	Potentially applicable: MNA may be applied alone or following treatment by other technologies in different plume areas. MNA is effective as a sole technology where source removal or plume treatment has been previously completed or where natural aquifer conditions are conducive to natural attenuation. MNA may be combined with active treatment, constituting a subsequent step in the treatment train. Effective MNA is indicated by declining contaminant concentrations and presence of degradation products. Naturally occurring phyto-attenuation is supplementing MNA in plume areas that where mature stands of trees/forested wetlands are present and not subject to redevelopment.	Retain
Engineered Phyto-remediation	Engineered Phyto-remediation	Planting Trees/Vegetation in Targeted Areas	Planted trees/vegetation act as mini- pumping wells with organics treated through biological treatment in the root zone, by root uptake, and by respiration through foliage.	Benefits: Uses natural transpiration and root zone enzymes to treat shallow groundwater contaminants. Often used as a containment strip between plume and receptors. Limitations: Depth of treatment is limited to <10 ft below the water table, young trees require an extended growth period before treatment becomes effective, trees must remain undisturbed through treatment period, for effective treatment/containment the treed area should be two growing seasons long relative to the travel time of groundwater through the treed area.	Low Limited depth of treatment relative to plume depths. Only effective seasonally (during the growing season) for deciduous trees.	Difficult Difficult in areas that will be developed because extensive area of dedicated land required for planting trees. Planted area should be two growing seasons thick for adequate plume treatment. Redevelopment in planted areas is severely restricted for duration of treatment.	Capital: Moderate Long-Term (OMM): Low to Moderate Overall: Low to Moderate	Not applicable: Only effective for shallow groundwater and during growing season (approximately half the year). This technology may interfere with the Tribes ability to redevelop portions of the Site.	Reject

Table 6B
Screening of Technologies and Process Options Applicable to Groundwater
Former Boeing-Tulalip Test Site
Marysville, Washington

General Response Action	Technology Type	Process Option	Description	General Benefits/Limitations	Effectiveness	Implementability	Cost	Screening Comments	Screening Result Retain/Reject
Containment	Physical	Slurry Walls, Low-Permeability Barrier Walls, or Sheet Pile Walls	Isolate contamination by emplacing barriers between contamination and receptors.	Benefits: Reliably minimize further migration of contamination for protection of receptors. Limitations: Does not provide treatment; not a permanent remedy. Groundwater physical containment would require groundwater extraction within the barrier with treatment and permitted discharge. Typically has low effectiveness in aquifers with high seepage velocities.	Low Containment of cVOCs does not reduce concentrations within the plume.	Difficult With the exception of Area 8, plumes extend deeper than typical installation depths for physical barriers. Implementability would be constrained by site activities and operations.	Capital: High Long-Term (OMM): Low Overall: High	Not applicable: Groundwater containment not required based on baseline risk assessment. Also, does not treat or remove mass.	Reject
	Hydraulic	Extraction Wells	Control/minimize migration of contaminated groundwater.	Benefits: Contains or slows expansion of plumes and/or contaminant flux from plumes for protection of receptors. Limitations: <i>Ex situ</i> treatment of extracted groundwater likely needed; does not provide effective mass reduction for cVOCs; not a permanent remedy. Potential to cause ground settlement and damage to nearby infrastructure where dewatering occurs.	Moderate Can be effective at containing groundwater contaminant migration, and may increase flushing rates, but not effective for treatment of cVOC plumes.	Moderate Requires extraction wells with power and conveyance lines, treatment system, and permitted discharge.	Capital: High Long-Term (OMM): High Overall: High	Not applicable: Groundwater containment not required based on baseline risk assessment, also inefficient mass removal. This technology may interfere with the Tribes ability to redevelop portions of the Site.	Reject
<i>Ex situ</i> Treatment	Physical	Pump and Treat (for mass removal): Extraction wells with various <i>ex situ</i> treatment options	Extraction of contaminated groundwater with the objective of plume treatment through COC mass reduction. Contaminated water treated <i>ex situ</i> through air stripping, granular activated carbon, or other water treatment technologies.	Benefits: Minimizes migration of contamination. Treatment or mass transfer of cVOCs in extracted groundwater. Moderately enhances groundwater flushing. Limitations: Inefficient as a mass removal technology for cVOCs because of substantial partitioning to aquifer soils and resulting long-term back diffusion. Contaminant concentrations in extracted groundwater decrease substantially during the early phase of system operation, resulting in low mass removal efficiency. Potential to cause ground/waste settlement and damage to nearby building, utilities, and other infrastructure in areas with poor soils and high water tables. In reduced aquifers, potential for biofouling due to aeration in treatment system. High extraction rates needed in aquifers with relatively high hydraulic conductivity. <i>Ex situ</i> treatment and discharge needed for large volume of discharge to sewer or surface water. Larger treatment system footprint than <i>in situ</i> technologies.	Low Does not effectively flush low permeability or low flow areas of the aquifer. Effectiveness decreases as contaminant concentrations decrease. Potential for problems with rebound once system is turned off.	Moderate Requires extraction wells with power and conveyance lines, treatment system, and permitted discharge.	Capital: High Long-Term (OMM): High Overall: High	Not effective: Decades of experience has shown pump and treat to be an ineffective mass removal technology for VOCs in groundwater. VOC concentrations in extracted groundwater decline rapidly despite substantial contaminant mass remaining in the aquifer due to the development of preferential flow paths under pumping conditions and the slow release of VOC mass by matrix back diffusion and desorption. This technology may interfere with the Tribes ability to redevelop portions of the Site.	Reject
		Dynamic Groundwater Recirculation (DGR)	Enhancement of standard pump and treat: involves groundwater recirculation through dynamic operation of injection/extraction wells under multiple configurations to change flow directions and gradients to maximize flushing and COC mass removal.	Benefits: Minimizes migration of contamination. Optimizes mass flux extraction and treatment of cVOCs in extracted groundwater. Ability to vary groundwater flow paths and remove contaminants from low flow and stagnation zones that occur with a standard pump and treat approach. Significantly faster restoration time frame than pump and treat. Limitations: Would require aboveground treatment before reinjection. In reduced aquifers, potential for biofouling due to aeration in treatment system and at injection wells, which increases OMM cost; larger treatment system footprint than <i>in situ</i> technologies and more wells than standard pump and treat.	Low to Moderate Effectiveness has not been thoroughly demonstrated yet, particularly on low-concentration plumes, because DGR is a relatively new approach. Theoretically more effective than pump and treat, but matrix back diffusion still represents a major challenge.	Difficult Requires injection/extraction wells with power and conveyance lines, treatment system, and permitted re-injection. High level of evaluation and operational reconfiguration to optimize mass flux removal. Biofouling likely at injection wells in reduced groundwater.	Capital: High Long-Term (OMM): High Overall: High	Potentially applicable: Improved mass removal relative to standard pump and treat. This technology may interfere with the Tribes ability to redevelop portions of the Site.	Retain

Table 6B
Screening of Technologies and Process Options Applicable to Groundwater
Former Boeing-Tulalip Test Site
Marysville, Washington

General Response Action	Technology Type	Process Option	Description	General Benefits/Limitations	Effectiveness	Implementability	Cost	Screening Comments	Screening Result Retain/Reject
	Biological	Anaerobic Enhanced Bioremediation	Injection of electron donor and nutrients to stimulate bacterial growth for degradation of cVOCs (cVOCs utilized as terminal electron acceptor).	Benefits: Anaerobic bioremediation has been demonstrated to be effective at the Site through treatability testing. Substrates are injected through wells (or direct injection via drill rigs) to create overlapping treatment between rows of injection wells/points. Treatability testing resulted in all TCE concentrations below the MCL with decreasing VC requiring subsequent natural attenuation. Limitations: Site challenges identified during treatability testing included low pH, bioaugmentation required, and a period of subsequent VC attenuation. Effectiveness of enhanced bioremediation is reduced in plume areas with lower cVOC concentrations and can be more challenging to establish sufficient biomass for sustained treatment.	High Established technology for cVOCs. Groundwater treatability testing demonstrated that enhanced bioremediation was highly effective at reducing concentrations of cVOCs in the Area 34 plume.	Moderate Requires installation of numerous injection wells/points to treat lateral and vertical extent of plumes. Does not require permanent installation of aboveground treatment equipment or conveyance piping. Installation of injection wells and piping may be coordinated with building construction or horizontal injection wells may be utilized beneath buildings. Paths for drilling and injection equipment will be required in forested areas. Mixing and injection equipment is mobilized for periodic injections.	Capital: Moderate to High Long-Term (OMM): Low Overall: Moderate	Potentially applicable: Aquifer conditions in some plumes are naturally anaerobic and reducing with biodegradation already occurring. Bioremediation pilot testing and treatability testing have shown anaerobic bioremediation to be effective at the Site.	Retain
		Aerobic (Cometabolic) Bioremediation	Injection of air and primary growth gases to stimulate bacterial growth and cometabolic degradation of cVOCs. By this approach, bacteria directly metabolize injected gases and oxygen and cVOCs are degraded by fortuitous side reaction.	Benefits: Aerobic bioremediation can treat TCE without creation of more toxic breakdown product (VC). Limitations: Spacing between injection wells is much closer than for anaerobic injection wells and injections would likely be required continuously to semi-continuously, frequently increasing the overall costs.	Low to Moderate Cometabolic treatment is not as well established. Has not been tested at the Site.	Difficult Injection of air and gases requires extensive infrastructure and O&M. Also, more tightly spaced injection wells required than for anaerobic treatment. Would require monitoring and additional health and safety due to explosion concerns.	Capital: High Long-Term (OMM): Moderate to High Overall: Moderate to High	Not Applicable: Does not compare well to anaerobic bioremediation. Technology is less established. Not site tested. Explosion concerns depending on injectate (e.g., propane and oxygen). More infrastructure and closer well spacing required at higher cost.	Reject
	In Situ Treatment	In Situ Chemical Reduction (ISCR)	Zero-Valent Iron (ZVI): A reducing agent (e.g., zero valent iron) is injected into the subsurface for destruction of cVOCs.	Benefits: <i>In situ</i> destruction of contaminants. Limitations: Treatment requires direct contact with cVOCs which is a challenge for low injectability agents (e.g., ZVI). Injection of dissolved substrates (e.g., ferrous sulfate) for <i>in situ</i> formation of reactive iron sulfides as a complementary addition to <i>in situ</i> bioremediation would be the preferred ISCR approach for the Site.	Low Due to low injectability, the most significant effectiveness challenge to ZVI ISCR is effective aquifer distribution to achieve the required contact with contaminants; ZVI ISCR would require excessively close injection spacing or a soil mixing approach, which is unreasonable given relatively low VOC concentrations, particularly in deep groundwater.	Difficult Implementation of ZVI ISCR is difficult due to excessively tight injection spacing or soil mixing requirements.	Capital: High Long-Term (OMM): High Overall: High	Not Feasible (ZVI): Prohibitive cost due to injection/distribution challenges and ZVI material cost.	Reject
			Ferrous Sulfate: Iron and sulfate reagents are injected to reduced aquifers to form reactive iron sulfide minerals in the aquifer matrix.	Benefits: <i>In situ</i> destruction of contaminants. Limitations: Treatment requires direct contact with cVOCs which is a challenge for low injectability agents (e.g., ZVI). Injection of dissolved substrates (e.g., ferrous sulfate) for <i>in situ</i> formation of reactive iron sulfides as a complementary addition to <i>in situ</i> bioremediation would be the preferred ISCR approach for the Site.	Moderate Injection of dissolved ferrous sulfate along with bioremediation substrates allows ISCR to be an effective chemical degradation pathway concurrent and complementary to biodegradation. Injected as a solute, ferrous sulfate is easily injected and effectively distributed in the aquifer by groundwater flow. Bioremediation substrates achieve the reduced aquifer conditions required for biological reduction of injected ferrous sulfate for precipitation of a fine coating of reactive iron sulfides on the aquifer matrix.	Easy Implementation of ISCR through ferrous sulfate injection concurrent with bioremediation injections is an easy enhancement.	Capital: Low Long-Term (OMM): Low Overall: Low (as an add-on to bioremediation substrate injection)	Potentially Applicable (Ferrous Sulfate): Could be used as a concurrent and complementary addition to bioremediation.	Retain
	Physical/Chemical	In Situ Chemical Oxidation (ISCO)	An oxidizing agent (e.g., persulfate or permanganate) is injected into the subsurface for destruction of cVOCs.	Benefits: <i>In situ</i> destruction of contaminants; can achieve cleanup faster than EISB. Limitations: Treatment requires direct contact with cVOCs over the extended period of matrix back diffusion, which is a challenge for oxidizing agents with relatively short period of reactivity. Multiple repeated injections of the longest lived oxidant (e.g., permanganate) are commonly required to address contaminant rebound resulting from matrix back diffusion. Excessive oxidant demand in reduced or organic carbon-rich aquifers reduces longevity and effectiveness, and requires greater oxidant mass. Oxidant demand testing performed with Site soils from the Admin Area (aerobic) and Area 34 (anaerobic) determined that Site oxidant demand was not excessive.	Moderate The most significant challenge of ISCO is the relatively short longevity of applicable oxidants, which is inadequate to achieve effective spreading in the aquifer or to address slow matrix back diffusion of contaminants; as a result, ISCO has more problems with rebound than EISB. ISCO would require significantly closer spaced injection wells and more injections than <i>in situ</i> bioremediation to achieve comparable effectiveness. ISCO would also slow or stall reductive dechlorination occurring naturally at some of the plumes.	Difficult Due to more closely spaced injection wells and more injections than required for <i>in situ</i> bioremediation. Additional handling and health and safety monitoring requirements are needed.	Capital: High Long-Term (OMM): Low Overall: High	Not feasible: Prohibitive costs due to the number of required injection wells, more injections required, and cost of oxidant.	Reject
		Air Sparge (AS)	Inject air beneath the water table. Physically removes volatile contaminants by stripping. Increases oxygen content of groundwater. Vapors typically collected using SVE.	Benefits: Volatilization is established technology for treating cVOCs. Limitations: Not effective in heterogeneous aquifer such as occur at the Site; siltier layers and preferential flow paths result in non-uniform sparging, which leaves much of the aquifer untreated. Reduces existing potential for reductive dechlorination under naturally anaerobic aquifer conditions. Substantial biofouling occurs in naturally anaerobic aquifers, such as occur at the Site.	Low Because of aquifer heterogeneity and substantial biofouling.	Difficult Tight well spacing required due to aquifer heterogeneity. Likely requires concurrent SVE; shallow water table makes vapor capture more difficult (high density of vertical or horizontal SVE wells necessary).	Capital: Moderate/High Long-Term (OMM): Moderate/High Overall: Moderate/High (a)	Not feasible: Ineffective due to aquifer heterogeneity and anaerobic conditions would cause substantial biofouling. Groundwater geochemistry would make this treatment system challenging.	Reject

Table 6B
Screening of Technologies and Process Options Applicable to Groundwater
Former Boeing-Tulalip Test Site
Marysville, Washington

General Response Action	Technology Type	Process Option	Description	General Benefits/Limitations	Effectiveness	Implementability	Cost	Screening Comments	Screening Result Retain/Reject
In Situ Treatment (continued)	Physical/ Chemical (continued)	Thermal Treatment	Removal of volatile contaminants through <i>in situ</i> heating (e.g., electrical resistance heating [ERH] or thermal conduction heating [TCH]) of vadose and aquifer zones.	Benefits: Removal of contaminants through heating to increase vapor COC pressure and volatilization rate. Treatment can be designed to treat both high- and low-permeability zones. Residual heat after active heating can temporarily enhance natural attenuation/bioremediation. Cleanup can be achieved in very short restoration timeframe. Low temperature thermal can also increase biotic and abiotic remediation rates over longer timeframes. Limitations: Energy-intensive, typically used in high-concentration source zones, not for downgradient plumes. Requires extensive belowground and aboveground infrastructure. Safety concerns within treatment area, especially where belowground conductive infrastructure (e.g., piping) extend aboveground.	High Established technology for cVOCs. Highly effective in removing cVOCs from low permeability aquifer matrices.	Difficult No high concentration source zones at the Site. Not applicable to large, diffuse plumes. Requires substantial aboveground and belowground infrastructure (heating wells, vapor recovery wells, power and vapor conveyance lines) and treatment system.	Capital: Very High Long-Term (OMM): Very High Overall: Very High	Not applicable: Technology is cost prohibitive unless treating high concentration source zones including DNAPL. No high concentration source zones are present at the Site.	Reject

Notes:
Green highlighting indicates a technology retained for assembling remedial alternatives in the feasibility study (FS). Remedial alternatives will undergo a detailed evaluation in the FS Report.
(a) Air sparge cost is high if typically concurrent SVE is also required.

Abbreviations and Acronyms:

Admin = Administration	MCL = maximum contaminant level
AS = air sparge	MNA = monitored natural attenuation
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act	O&M = operations and maintenance
cDCE = 1,2-dichloroethene	OMM = operations, maintenance, and management
COC = chemical of concern	RAO = remedial action objective
cVOC = chlorinated volatile organic compound	Site = former Boeing-Tulalip Test Site
DGR = dynamic groundwater recirculation	SVE = soil vapor extraction
DNAPL = dense nonaqueous phase liquid	TCE = trichloroethene
EISB = enhanced <i>in situ</i> bioremediation	TCH = thermal conduction heating
ERH = electrical resistance heating	Tribes = Tulalip Tribes
FS = feasibility study	VC = vinyl chloride
ft = feet	VOC = volatile organic compound
ISCO = <i>in situ</i> chemical oxidation	ZVI = zero-valent iron
ISCR = <i>in situ</i> chemical reduction	

Table 7
Retained Technologies by Area
Former Boeing-Tulalip Test Site
Marysville, Washington

General Response Action	Retained Technologies	Media Addressed	Area 1 (a)	Area 5 (a)	Area 41 (a)	Admin Area (b)	Area 34 (c)	Area 8 (d)
No Action	No Action	Groundwater/ Soil Vapor	X			X	X	X
Institutional Controls/ Engineering Controls	Restrictive Environmental Covenant, Signage, Access Agreements	Groundwater/ Soil Vapor	X			X	X	X
	Vapor Barrier (Engineering Controls)	Soil Vapor	X			X	X	X
Natural Attenuation	MNA	Groundwater	X			X	X	X
<i>In Situ</i> Treatment (Biological/ Physical/ Chemical)	Anaerobic Enhanced Bioremediation	Groundwater	X			X	X	
	ISCR - Ferrous Sulfate	Groundwater	X			X		
<i>Ex Situ</i> Treatment (Physical)	DGR	Groundwater	X					
Groupings for Alternatives Evaluation:			Category A			Category B	Category C	Category D

Table 7
Retained Technologies by Area
Former Boeing-Tulalip Test Site
Marysville, Washington

Notes:

(a) Stable plumes where limited biodegradation is occurring without clear decreasing concentration trends observed during the remedial investigation.

(b) Plume where source removal has been completed, groundwater concentrations are decreasing, and the plume area is shrinking. DGR is not included as a retained technology due to source removal and substantial plume attenuation.

(c) Treatability testing completed in Area 34 resulted in TCE and cDCE below the PRG; concentrations of breakdown product VC are generally decreasing but remain above the PRG at more than half of the wells. DGR is not included as a retained technology for this plume where treatment has already been completed. The addition of ISCR with ferrous sulfate to bioremediation is not applicable for VC treatment.

(d) Plume composed of relatively low concentrations of VC above the PRG. Currently two wells have VC concentrations exceeding the PRG. Released TCE has been reduced to VC under natural site conditions. Clear evidence of naturally occurring attenuation resulting in shrinking plume. DGR is not included as a retained technology where natural treatment is already occurring. The addition of ISCR with ferrous sulfate to bioremediation is not applicable for VC treatment.

Abbreviations and Acronyms:

Admin = Administration

cDCE = cis-1,2-dichloroethene

DGR = dynamic groundwater recirculation

ISCR = *In situ* chemical reduction

MNA = monitored natural attenuation

PRG = preliminary remediation goals

TCE = trichloroethene

VC = vinyl chloride

Table 8A
Proposed Alternatives - Category A Areas of Concern
Former Boeing-Tulalip Test Site
Marysville, Washington

Category A Description (Areas 1, 5, 41): Stable plumes where limited natural biodegradation to cDCE is occurring and without clear decreasing concentration trends observed during the remedial investigation.

Alternative Number:	Alternative A1	Alternative A2	Alternative A3	Alternative A4	Alternative A5
Alternative Name:	No Action	Institutional/Engineering Controls	Institutional/Engineering Controls and MNA	EISB and MNA	DGR and MNA
Alternative Description:	<p>No additional remedial action:</p> <ul style="list-style-type: none"> • No remedial action and no groundwater or soil vapor monitoring would be performed. 	<p>Institutional/engineering controls for the groundwater plume and soil vapor:</p> <ul style="list-style-type: none"> • Institutional controls consisting of an environmental covenant to limit activities that could result in exposure to contaminated media (groundwater and soil vapor). • Vapor barrier installed for future buildings, if required (to address soil vapor). • Long-term, periodic groundwater monitoring. 	<p>MNA for the groundwater plume:</p> <ul style="list-style-type: none"> • Groundwater monitoring to track natural attenuation of contaminated groundwater (MNA): <ul style="list-style-type: none"> - Naturally occurring biotic and abiotic degradation and other attenuation processes. - Phyto-attenuation where groundwater plumes extend beneath existing forest and forested wetlands which may be excluded from future development (e.g., portions of Area 1). • Institutional controls consisting of an environmental covenant to limit activities that could result in exposure to groundwater or soil vapor until RAOs are met. • Vapor barrier installed during construction for future buildings, if required. 	<p>EISB and subsequent MNA for the groundwater plume:</p> <ul style="list-style-type: none"> • <i>In situ</i> groundwater treatment using EISB with staggered injection rows. Monitoring after each injection event to monitor remedial progress. • Subsequent remediation of groundwater through naturally occurring biotic and abiotic degradation and other attenuation processes (MNA). Continued monitoring with routine groundwater sampling. • Institutional/engineering controls (including potential vapor barrier installed during construction for future buildings) will be in place as required until RAOs are met. 	<p>DGR and subsequent MNA for the groundwater plume:</p> <ul style="list-style-type: none"> • DGR with a mix of injection and extraction wells to enhance groundwater flushing and optimize mass removal. Ongoing performance monitoring during operation. • Subsequent remediation of groundwater through naturally occurring biotic and abiotic degradation and other attenuation processes (MNA). Continued monitoring with routine groundwater sampling. • Institutional/engineering controls (including potential vapor barrier installed during construction for future buildings) will be in place as required until RAOs are met.

Table 8A
Proposed Alternatives - Category A Areas of Concern
Former Boeing-Tulalip Test Site
Marysville, Washington

Abbreviations and Acronyms:

cDCE = cis-1,2-dichloroethene

DGR = dynamic groundwater recirculation

EISB = enhanced *in situ* bioremediation

MNA = monitored natural attenuation

RAOs = remedial action objectives

Table 8B
Proposed Alternatives - Category B Area of Concern
Former Boeing-Tulalip Test Site
Marysville, Washington

Category B Description (Administration Area): Naturally aerobic plume where groundwater cVOC concentrations have been decreasing and the plume area has been shrinking since completion of source removal.

Alternative Number:	Alternative B1	Alternative B2	Alternative B3	Alternative B4
Alternative Name:	No Action	Institutional/Engineering Controls	Institutional/Engineering Controls and MNA	EISB and MNA
Alternative Description:	<p>No additional remedial action:</p> <ul style="list-style-type: none"> • No remedial action and no groundwater or soil vapor monitoring would be performed. 	<p>Institutional/engineering controls for the groundwater plume and soil vapor:</p> <ul style="list-style-type: none"> • Institutional controls consisting of an environmental covenant to limit activities that could result in exposure to contaminated media (groundwater and soil vapor). • Vapor barrier installed for future buildings, if required (to address soil vapor). • Long-term, periodic groundwater monitoring. 	<p>Institutional/Engineering Controls for the groundwater plume and soil vapor and MNA for the groundwater plume:</p> <ul style="list-style-type: none"> • Groundwater monitoring to track natural attenuation of contaminated groundwater (MNA): <ul style="list-style-type: none"> - Naturally occurring biotic and abiotic degradation and other attenuation processes. - Phyto-attenuation where groundwater plumes extend beneath existing forest and forested wetlands which may be excluded from future development (e.g., distal portion of Admin Plume). • Institutional controls consisting of an environmental covenant to limit activities that could result in exposure to groundwater or soil vapor until RAOs are met. • Vapor barrier installed during construction for future buildings, if required. 	<p>EISB and subsequent MNA for the groundwater plume:</p> <ul style="list-style-type: none"> • <i>In situ</i> groundwater treatment using EISB with staggered injection rows. Monitoring after each injection event to monitor remedial progress. • Subsequent remediation of groundwater through naturally occurring biotic and abiotic degradation and other attenuation processes (MNA). Continued monitoring with routine groundwater sampling. • Institutional/engineering controls (including potential vapor barrier installed during construction for future buildings) will be in place as required until RAOs are met.

Abbreviations and Acronyms:

cVOC = chlorinated volatile organic compound

EISB = enhanced *in situ* bioremediation

MNA = monitored natural attenuation

RAOs = remedial action objectives

Table 8C
Proposed Alternatives - Category C Area of Concern
Former Boeing-Tulalip Test Site
Marysville, Washington

Category C Description (Area 34): Shrinking groundwater plume where treatability testing has resulted in reduction of TCE to VC, and VC concentrations are decreasing.

Alternative Number:	Alternative C1	Alternative C2	Alternative C3	Alternative C4
Alternative Name:	No Action	Institutional/Engineering Controls	Institutional/Engineering Controls and MNA	EISB and MNA
Alternative Description:	<p>No additional remedial action:</p> <ul style="list-style-type: none"> • No remedial action and no groundwater or soil vapor monitoring would be performed. 	<p>Institutional/engineering controls for the groundwater plume and soil vapor:</p> <ul style="list-style-type: none"> • Institutional controls consisting of an environmental covenant to limit activities that could result in exposure to groundwater or soil vapor. • Vapor barrier installed for future buildings, if required. • Long-term, periodic groundwater monitoring. 	<p>Institutional/Engineering Controls for the groundwater plume and soil vapor and MNA for the groundwater plume:</p> <ul style="list-style-type: none"> • Groundwater monitoring to track natural attenuation of contaminated groundwater (MNA): <ul style="list-style-type: none"> - Naturally occurring biotic and abiotic degradation and other attenuation processes. - Phyto-attenuation where groundwater plumes extend beneath existing forest and forested wetlands which may be excluded from future development (e.g., southern portion of Area 34). • Institutional controls consisting of an environmental covenant to limit activities that could result in exposure to groundwater or soil vapor until RAOs are met. • Vapor barrier installed during construction for future buildings, if required. 	<p>EISB and subsequent MNA for the groundwater plume:</p> <ul style="list-style-type: none"> • Further <i>in situ</i> groundwater treatment to continue or enhance EISB from the completed treatability testing. Monitoring after each injection event to monitor remedial progress. • Subsequent remediation of groundwater through naturally occurring biotic and abiotic degradation and other attenuation processes (MNA). Continued monitoring with routine groundwater sampling. • Institutional/engineering controls (including potential vapor barrier installed during construction for future buildings) will be in place as required until RAOs are met.

Abbreviations and Acronyms:

EISB = Enhanced *in situ* bioremediation

MNA = monitored natural attenuation

TCE = trichloroethene

VC = vinyl chloride

RAOs = remedial action objectives

Table 8D
Proposed Alternatives - Category D Area of Concern
Former Boeing-Tulalip Test Site
Marysville, Washington

Category D Description (Area 8): Shrinking groundwater plume where natural biodegradation has resulted in reduction of TCE to VC, and VC concentrations are decreasing.

Alternative Number:	Alternative D1	Alternative D2	Alternative D3
Alternative Name:	No Action	Institutional/Engineering Controls	Institutional/Engineering Controls and MNA
Alternative Description:	<p>No additional remedial action:</p> <ul style="list-style-type: none"> • No remedial action and no groundwater or soil vapor monitoring would be performed. 	<p>Institutional/engineering controls for the groundwater plume and soil vapor:</p> <ul style="list-style-type: none"> • Institutional controls consisting of an environmental covenant to limit activities that could result in exposure to groundwater or soil vapor. • Vapor barrier installed for future buildings, if required. • Long-term, periodic groundwater monitoring. 	<p>Institutional/Engineering Controls for the groundwater plume and soil vapor and MNA for the groundwater plume:</p> <ul style="list-style-type: none"> • Groundwater monitoring to track natural attenuation of contaminated groundwater (MNA): <ul style="list-style-type: none"> -Naturally occurring biotic and abiotic degradation and other attenuation processes. - Phyto-attenuation where groundwater plumes extend beneath existing forest and forested wetlands which may be excluded from future development. • Institutional controls consisting of an environmental covenant to limit activities that could result in exposure to groundwater or soil vapor until RAOs are met. • Vapor barrier installed during construction for future buildings, if required.

Abbreviations and Acronyms:

MNA = monitored natural attenuation

TCE = trichloroethene

VC = vinyl chloride

RAOs = remedial action objectives

EPA Approval Letter and Responses to Draft Report Comments from EPA and the Tribes



**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10**

1200 Sixth Avenue, Suite 155
Seattle, WA 98101-3123

SUPERFUND AND
EMERGENCY
MANAGEMENT DIVISION

March 2, 2023

Nick Garson, P.G.

Manufacturing, Supply Chain & Operations 1 Environment, Health, & Safety
Remediation Group – Senior Project Manager
Bldg. 10-20, MC 9U4-26
800 N 6th Street, Renton, WA 98055-1409

Re: EPA Response to Boeing Feasibility Work Plan & Comments – Former Boeing Tulalip Test Site
Marysville, Washington
Project No. 0025087.022.012

Dear Mr. Garson:

This letter is to provide a timeline of events and correspondence regarding the transition of the Feasibility Study Work Plan (FSWP) to the Feasibility Study (FS). Boeing submitted the Draft Focused Feasibility Study Work Plan on October 18, 2022.¹ EPA reviewed and provided comments to the FSWP on December 6, 2022. A site visit was held at the Boeing Tulalip Test Site on December 14, 2022, along with a meeting to discuss and provide clarity on EPA's comments. Representatives of Boeing, Landau, Tulalip Tribes, EPA, and Jacobs were in attendance. Boeing agreed to address EPA's comments on the FSWP and requested an extension for the submittal of the revised FS WP from January 6, 2023, to January 20, 2023. EPA agreed to the extension.

Boeing submitted the FSWP in a timely manner. Unfortunately, EPA identified several deficiencies in the revised FSWP. EPA responded to the submittal in a January 27, 2023, email (Attachment A). The email provided Boeing with the permission to initiate the FS process and provided comments to be addressed in the FS Draft Submittal which must be submitted 120 days from the approval email. EPA, Landau, and Boeing had a meeting on February 15, 2023, to discuss the comments in EPA's email. The agenda from the meeting can be seen in Attachment B. EPA's response to questions raised by Boeing during the meeting are provided in Attachment C. No responses to Attachment C are required.

EPA looks forward to receiving a draft FS from Boeing that includes a robust screening of alternatives with ample justification of each technology. If you have any questions or concerns, please do not hesitate to contact me at feldman.rebecca.c@epa.gov or by phone at 206-553-0479.

Sincerely,
Rebecca C. Feldman
Remedial Project Manager
1200 Sixth Avenue, Suite 155,
Seattle WA 98101

Feldman,
Rebecca
C

Digitally signed
by Feldman,
Rebecca C
Date: 2023.03.02
14:59:00 -08'00'

¹ In the ASAOC Boeing was directed to submit a draft Feasibility Study, not a Focused Feasibility Study. We now refer to the document as the draft Feasibility Study Work Plan.

Attachment A. Email Correspondence

2/16/23, 12:04 PM

Mail - Feldman, Rebecca (Becca) - Outlook

EPA Response to Submittals

Feldman, Rebecca (Becca) <Feldman.Rebecca.C@epa.gov>

Fri 1/27/2023 2:19 PM

To: nick.garson@boeing.com <nick.garson@boeing.com>; Clint Jacob <CJacob@landauinc.com>; Sarah Fees <SFees@landauinc.com>

Cc: Bott, Dustan <Bott.Dustan@epa.gov>; Peshek, Kathleen (she/her/hers) <Peshek.Kathleen@epa.gov>; Forbes, Liz/SEA <Liz.Forbes@jacobs.com>; vstreeter@tulaliptribes-nsn.gov <vstreeter@tulaliptribes-nsn.gov>; Allison Warner <awarner@tulaliptribes-nsn.gov>

Good afternoon,

Thank you for your submittals of:

1. 4th Quarter 2022 Progress Report
2. Final Revision of the Feasibility Study Work Plan

Acknowledging our agreement to move forward and initiate the process of the FS, EPA would also like to see the following be addressed in the FS Draft Submittal:

1. Section 1.4.2: Please include a discussion of the potential back diffusion going on at Area 41.
2. Section 2.1, RAO-2: Please remove the words "where feasible".
3. Section 3.0: As discussed in previous meetings while EPA acknowledges that all of the initial sources have been excavated from the site. EPA does not concur that there are no sources on site. It is mentioned in the comments that there is suspicion of back diffusion, functioning as a secondary source in Area 41. Please revise the paragraph under the bulleted points to present this information.
4. Section 3.0: As discussed in a previous email, EPA expects the evaluation of the two additional technologies for alternative screening in the FS.
5. Figures: It would be useful to include a symbology that indicates where the wetlands occur on site. Please revise the site figures to show this.
6. Table 3: EPA expects additional evaluation in the FS to show that phytoremediation is viable if it is included as a part of MNA.

If you have any questions or concerns, feel free to send me an email or set up a Teams meeting.

Kind regards,

Rebecca Feldman

Remedial Project Manager

Superfund & Emergency Management Division

U.S. EPA Region 10

feldman.rebecca.c@epa.gov

Phone: 206-553-0479

Attachment B. February 2023 Meeting Agenda

BTTS Meeting at Landau Associates Northgate Office

Discuss EPA questions about Area 41 back diffusion and other remedial technologies

February 15, 2023

1. What is the administrative status of FS WP? Review and approval letter? Final FSWP submittal?
2. Area 41 back diffusion discussion
 - Why is EPA particularly concerned about back diffusion in A41?
 - Similar to other areas, the recessional outwash in A41 is primarily sand to silty sand with thin discrete lenses of silt. Site soils do not range from sandy silt to clay, as noted by EPA in memo.
 - Cross-sections
 - DG Figure 34- A41 hydrogeo xsect
 - DG Figure 30- A41 TCE xsect
 - DG Figure 17- A5 hydrogeo xsect with similar lithology
3. Electrokinetics- suited for low permeability soils
 - EPA thoughts?
 - Not applicable to sandy soils at BTTS. Agreed?
 - How does EPA understand setup and implementation for large diffuse plume?
 - Very intensive infrastructure required >> dynamic groundwater recirculation, > electrical resistance heating. This technology is for small high concentration source areas in clayey soils (ERH is also applicable for these situations.)
 - How apply to 42-acre A41 plume? Paduca electrode spacing on 7-ft centers (vs ERH at 15 ft spacing= 4x as many electrodes). Would require 47,563 electrodes for A41. Enormous cost. Not implementable with site redevelopment.
 - Further induces low pH beyond typical EISB, counterproductive to EISB
4. Horizontal injection wells
 - Yes, possible applications beneath buildings etc. Will be evaluated as part of Engineering Design along with vertical wells.
 - EPA thoughts on how applied to elongated plumes? EPA suggestion “horizontal wells that run along the plume”?
 - Injection rows need to be perpendicular vs parallel to plume axis (groundwater flow) – A34 TT Figure 7 plan view
 - Stacked horizontal wells required to treat full plume vertical interval- A34 TT Figure 8 xsect
 - Any row of vertical IWs could be replaced by one or more stacked horizontal wells. Will describe in FS report.
 - Benefits- reach beneath buildings, fewer locations to inject
 - Challenges- higher drilling cost, setback distance min 5x depth of vertical screen, achieving uniform distribution of injection fluid from long screen (vs 20 ft vertical screen)
5. “Bioremediation may require different nutrients/microorganisms in the different areas”?
 - Short bioremediation technology overview (10 minute PowerPoint)
 - Detailed design in EDR

Attachment C, REVIEW COMMENTS AND RESPONSES
Responses to Questions Posed by Boeing & Landau during 02/15/2023 meeting, Former Boeing Tulalip Test Site
Reviewers: EPA Review Date: February 2023

ITEM	PAGE	BOEING/LANDAU COMMENT	EPA RESPONSE
1	General	What is the administrative status of FS WP? Review and., approval letter? Final FSWP submittal?	<p>EPA first informed Boeing that it should proceed with developing the FS during the December 14, 2022, meeting with Boeing. EPA again provided Boeing the necessary approval to begin drafting the FS in the January 27, 2023 email correspondence (Attachment A). Pursuant to the 2010 ASAOC, Boeing must provide a draft FS to EPA 120 days from the January 27, 2022, written notification that Boeing may proceed with the FS. The draft FS must be submitted by May 27, 2023.</p> <p>EPA is providing written responses to the questions raised by Boeing during the February 15, 2023 meeting. No response is required.</p>

Attachment C, REVIEW COMMENTS AND RESPONSES
Responses to Questions Posed by Boeing & Landau during 02/15/2023 meeting, Former Boeing Tulalip Test Site
Reviewers: EPA Review Date: February 2023

ITEM	PAGE	BOEING/LANDAU COMMENT	EPA RESPONSE
2	General	<p>Area 41 back diffusion discussion</p> <ul style="list-style-type: none"> - Why is EPA particularly concerned about back diffusion at A41? - Similar to other areas, the recessional outwash in A41 is primarily sand to sily sand with discrete lenses of silt. Site soils do not range from sandy silt to clay as noted by EPA in this memo. - Cross Sections – DG Figure 34, - A41 hydrogeo xsect, DG Figure 30 – A41 TCE xsect, DG Figure 17 – A5 hydrogeo xsect with similar lithology 	<p>EPA is particularly concerned about back diffusion (BD) as a secondary source at Area 41 and has consistently documented this concern. EPA documented this concern in its comments on the October 2020 Data Gaps deliverable 0 .</p> <p>EPA acknowledges that the overall area does have a similar geology of recessional outwash.</p> <p>However, the distinction between Area 41 and other site areas is the occurrence of clayey-silt lenses that occur within the TCE plume area, as illustrated in the Data Gaps document Cross Section A-A'. As mentioned in the meeting, the spacing between monitoring wells where geologic data was obtained is up to 800 ft and may indicate the lenses are larger than first interpreted. Multiple studies show that back diffusion can occur and persist in clay lenses, some being as thin as 0.2 m thick (Parker et al. 2008 and Tatti et at. 2018). This includes a study of a sandy aquifer that contains clay silt lenses (Parker et al. 2008).</p>

Attachment C, REVIEW COMMENTS AND RESPONSES
Responses to Questions Posed by Boeing & Landau during 02/15/2023 meeting, Former Boeing Tulalip Test Site
Reviewers: EPA Review Date: February 2023

ITEM	PAGE	BOEING/LANDAU COMMENT	EPA RESPONSE
3	General	<p>Electrokinetics – suited for low permeability soils</p> <ul style="list-style-type: none"> - EPA thoughts? - Not applicable to sandy soils at BTTS, agreed? - How does EPA understand setup and implementation for large diffuse plume? - Very intense infrastructure required >> dynamic groundwater recirculation, > electrical resistance heating. The technology is for small high concentration source areas in clayey soil (ERH is also applicable for these situations) - How to apply to a 42-acre plume? Paduca electrode spacing on 7 ft centers (vs ERH at 15 ft spacing = 14x as many electrodes). Would require 47,563 electrodes for A41. Enormous cost. Not implementable with site redevelopment. - Further indicates low pH beyond typical EISB counterproductive to EISB 	<p>The CERCLA process requires different technologies to be screened during the FS so that EPA can select a preferred alternative for the remedial action at the site. Alternatives can consist of a multiple-technology approach to remediation at the site.</p> <p>EPA agrees that the electrokinetic technique is not suitable for the entire site, as the majority of Area 41 consists of sandy soil.</p> <p>However, this technology could be useful to target the clayey-silt lenses at the site to aggressively treat BD and therefore should be screened appropriately in the FS. Using a targeted approach would have a smaller overall footprint in the remedial process and would likely reduce the potential of slow releases in the future, replenishing sections of the plume with more TCE. Mitigating this process of further contamination would reduce the risk of a prolonged remediation process due to slow replenishment of TCE from the BD source.</p> <p>In response to comments regarding pH, strategies are available within EK that limit the changes in pH (Villaseñor et al, 2016).</p> <p>Comments regarding size, cost, and time will be addressed during the FS screening process.</p>

Attachment C, REVIEW COMMENTS AND RESPONSES
Responses to Questions Posed by Boeing & Landau during 02/15/2023 meeting, Former Boeing Tulalip Test Site
Reviewers: EPA Review Date: February 2023

ITEM	PAGE	BOEING/LANDAU COMMENT	EPA RESPONSE
4	General	<p>Horizontal Injection Wells</p> <ul style="list-style-type: none"> - Yes, possible applications beneath buildings etc. Will be evaluated as part of the Engineering Design along with vertical wells - EPA thoughts on how applied to elongated plumes? EPA suggestion “horizontal wells that run along the plume”? – Injection rows need to be perpendicular vs parallel to plum axis (groundwater flow) – A34 TT Figure 7 plan view, Stacked horizontal wells required to treat full plume vertical interval – A34 TT Figure 8 xsect - Any row of vertical IWs could be replaced by one or more stacked horizontal wells. Will describe in FS report. – Benefits: reach beneath buildings, fewer locations to inject, Challenges: higher drilling cost, setback distance min 5x depth of vertical screen, achieving uniform distribution of injection fluid from long screen (vs 20 ft vertical screen) 	<p>EPA requested Boeing/Landau consider Horizontal Wells to ensure the technology is included in the screening process. Consideration of this technology would be consistent with the Tribes comments and would address concerns that the Tribe has regarding potential development plans. The exact implementation of this technology, if selected, can be determined during the remedial design process.</p>

Attachment C, REVIEW COMMENTS AND RESPONSES
Responses to Questions Posed by Boeing & Landau during 02/15/2023 meeting, Former Boeing Tulalip Test Site
Reviewers: EPA Review Date: February 2023

ITEM	PAGE	BOEING/LANDAU COMMENT	EPA RESPONSE
5	General	<p>Bioremediation may require different nutrients/microorganisms in the different areas”?</p> <ul style="list-style-type: none"> - Short bioremediation technology overview (10-minute PowerPoint) - Detailed design in EDR 	<p>The plumes at the site have different environments (anaerobic vs aerobic), different hydrogeology, and different sources/spills causing the TCE plumes. Boeing has grouped them together for remediation selection. This grouping is concerning to EPA because no remedy has been selected yet and the selected remedy may not be the same for different plumes. Individual plumes may require different nutrients/microorganisms for injection, or injections at different percentages. Boeing must ensure all technical factors are properly considered at each plume and are documented in the FS.</p>

References

- Blue, J., Boving, T., Tuccillo, M.E., Koplos, J., Rose, J., Brooks, M., Burden, D. 2022. Diffusion from Low-Conductivity Matrices Case Studies of Remedial Strategies. Water 2023, 15, 570. <https://doi.org/10.3390/w15030570>
- Mena, E., Villaseñor, J., Rodrigo, A.A., Cañizares, P. 2016. Electrokinetic remediation of soil polluted with insoluble organics using biological permeable reactive barriers: Effect of periodic polarity reversal and voltage gradient. J. Chemical Engineering Journal 299, 30-36.
- Parker, B.L., Chapman, S.W., Guilbeault, M.A., 2008. Plume persistence caused by back diffusion from thin clay layers in a sand aquifer following TCS source-zone hydraulic isolation. J. Contam. Hydrol. 102, 86-104.

Attachment C, REVIEW COMMENTS AND RESPONSES
Responses to Questions Posed by Boeing & Landau during 02/15/2023 meeting, Former Boeing Tulalip Test Site
Reviewers: EPA Review Date: February 2023

Rabbi, M.F., Clark, B., Gale, R.J., Ozsü-Acar, E., Pardue, J., Jackson, A. 2000. In situ TCE bioremediation study using electrokinetic cometabolite injection. J. Waste Management 20, 279-286.

Tatti, F., Petrangeli, M.P., Sappa, G., Raboni, M., Arjmand, F., Paolo, V. 2018. Contaminant back-diffusion from low-permeability layers as affected by groundwater velocity: A laboratory investigation by box model and image analysis. J. Science of the Total Environment 622-623, 164-171.

REVIEW COMMENTS AND RESPONSES

Agency Review Draft

Draft Focused Feasibility Study Work Plan, Former Boeing Tulalip Test Site

Reviewers: EPA/Jacobs

Review Date: November 2022

ITEM	PAGE	SECT/PARA	COMMENT	RESPONSE
EPA letter		Final Para	Boeing must fully incorporate EPA's comments in the FS Workplan and submit the deliverable by January 6, 2023.	In order to comply with EPA's request for additional information below, Boeing has requested that EPA grant an extension for submittal of the revised FS Workplan from January 6 to January 20, 2023. To allow enough time for Boeing to incorporate any additional agency feedback in the revised deliverable, Boeing requests confirmation from EPA by January 6, 2023 that the responses contained within this Issues Register are acceptable.

REVIEW COMMENTS AND RESPONSES

Agency Review Draft

Draft Focused Feasibility Study Work Plan, Former Boeing Tulalip Test Site

Reviewers: EPA/Jacobs

Review Date: November 2022

ITEM	PAGE	SECT/PARA	COMMENT	RESPONSE
1	General		<p>This document needs to meet the requirements specified for a Feasibility Study Work Plan as noted in the Administrative Settlement Agreement and Order on Consent for RI/FS and outlined in the Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (1998).</p> <p>This document does not include the necessary information. Please revise and add the following information:</p> <ul style="list-style-type: none"> • Update the document title to Feasibility Study Work Plan • Include a description of the contents of the FS (table of contents and/or description of FS sections) • Scope of Work • Schedule • Work Plan rationale • Background information and information from initial evaluation • Prior and ongoing feasibility study work • Hydrogeology and water quality • Assessment of treatment technologies 	<p>A “focused” work plan for the FS was previously agreed with EPA (Dustan Bott) to expedite the FS process especially since no additional FS investigation (scope of work) activities are planned for the site. The purpose of this “focused” WP was to come to general concurrence with EPA on PRGs, RAOs and technology screening, while moving ahead quickly to complete the FS Report.</p> <p>Following discussion during our project meeting on December 14, 2022, we agreed to revise the title to Feasibility Study Work Plan and to add the additional background information requested, with the exception of the strike out bullets. We discussed during the meeting that scope of work and assessment are adequately addressed in the draft FS WP by Purpose and Screening of Technologies sections, respectively. There is no prior and ongoing FS work to summarize for this project. Adding this requested information is the reason for extending the due date for the revised document to January 20. The additional background information will also be provided in the FS report.</p>

REVIEW COMMENTS AND RESPONSES

Agency Review Draft

Draft Focused Feasibility Study Work Plan, Former Boeing Tulalip Test Site

Reviewers: EPA/Jacobs

Review Date: November 2022

ITEM	PAGE	SECT/PARA	COMMENT	RESPONSE
2	General		Please add a background section which includes current site-specific characteristics, nature and extent of contamination, contaminant fate and transport, and a preliminary CSM section to provide general background for the site. Without any background information, it is difficult for an independent reader to understand the site and why certain remedial alternatives were evaluated or retained.	Agreed. See response to comment #1.
3	General		Area 14 had VC concentrations above the noted PRG. Will that area be discussed in the FS?	All VOCs measured at Area 14 replacement wells in 2019 as part of the Data Gaps Investigation were below proposed PRGs. VC was detected at well TGW-128 ranging from 0.21-0.83, but results were below the proposed PRG of 2 ug/L. Area 14 will not be evaluated for cleanup options in the FS due to concentrations below the proposed PRG.
4	General		Please provide more detail on why more aggressive/source treatment alternatives were not retained. Please consider adding alternatives that address back diffusion, the current source of the plume. This can be utilized for a targeted and/or expedited remediation cleanup.	Agree to provide more detail regarding source treatment and back diffusion. We will add the following explanations to the section on Identification and Screening of Remedial Action technologies: -from the RI, add explanation that no persistent TCE DNAPL sources exist at the site -from the Treatability Test Completion report, explanation that appropriate treatment technologies must provide in an extended period of treatment to address matrix back diffusion.

REVIEW COMMENTS AND RESPONSES

Agency Review Draft

Draft Focused Feasibility Study Work Plan, Former Boeing Tulalip Test Site

Reviewers: EPA/Jacobs

Review Date: November 2022

ITEM	PAGE	SECT/PARA	COMMENT	RESPONSE
5	General		Are remediation time frames for alternatives evaluated in the FS? Alternatives with more aggressive timeframe should be considered, specifically for areas that may be redeveloped in the near future.	<p>Yes, the remediation time frames will be evaluated as part of the FS. Remediation time frames will affect cost-benefit analyses for alternative comparisons. Various factors control the achievable remediation time frames, including, the widespread and diffuse nature of TCE mass within the plumes, no high concentration sources, and matrix back diffusion.</p> <p>Preferred treatment approaches have been considered for compatibility with the Tulalip Tribes' potential redevelopment plans, in areas for which Boeing formerly operated.</p>
6	General		Please revise the remediation alternatives to be separated by media (i.e. separate groundwater and vapor). Please create a separate table for the VI related alternatives.	<p>Based on clarifying discussions during the December 14, 2022 project meeting, we agree to separate the technology screening by media, providing two separate screening tables. However, the assembled remedial alternatives, which include various technologies, will include all media subject to treatment (this is per the 1998 EPA RI/FS guidance, Figure 4-2). Within the description of each alternative, we will clarify which media are treated by each technology.</p>

REVIEW COMMENTS AND RESPONSES

Agency Review Draft

Draft Focused Feasibility Study Work Plan, Former Boeing Tulalip Test Site

Reviewers: EPA/Jacobs

Review Date: November 2022

ITEM	PAGE	SECT/PARA	COMMENT	RESPONSE
7	General		If MNA is retained, additional information and analysis will need to be provided to confirm that MNA is a viable alternative for the noted plumes (i.e. MNA Checklist, specific aerobic/anaerobic conditions).	Agreed. The evaluation in the FS will determine if MNA is a viable alternative as a standalone technology for each plume through additional analysis of existing data. Our preliminary review indicates that MNA may be applicable as a standalone technology in Area 8 and the Admin Area. For other areas, MNA will likely only be retained as a part of a treatment train, as a polishing step following active treatment.
8	2	Second bullet	"beneath Coho Creek". Coho Creek is shown to the east of the project area. Please label Coho Creek where the Area 5 plume is, or identifying as drainage ditches, etc. on figures and in text.	Agreed, Coho Creek will be labeled on Figures 1 and 2. By way of clarification, it is the West Fork Quilceda Creek (WFQC) which is located to the east of the site, while Coho Creek runs south along West Security Road.
9	2	Third bullet	Same as above regarding Coho Creek	Same as above.
10	3	Indoor Air PRGs/first paragraph	Last sentence only mentions lack of TCE in the shallowest groundwater samples, as an incomplete pathway for vapor intrusion. Are the breakdown products also absent?	Breakdown products are also absent. Will add that clarification.
11	3	First Bullets	The RAOs should include measurable objectives. Suggest rewording the RAOs as follows: "RAO-1: Prevent exposure to contaminated groundwater above PRGs for protection of construction worker incidental/ingestion/direct contact. RAO-2: Reduce groundwater COC concentrations below the site PRGs to their expected beneficial uses where feasible (aquifer restoration)."	Agreed. Will revise wording.

REVIEW COMMENTS AND RESPONSES

Agency Review Draft

Draft Focused Feasibility Study Work Plan, Former Boeing Tulalip Test Site

Reviewers: EPA/Jacobs

Review Date: November 2022

ITEM	PAGE	SECT/PARA	COMMENT	RESPONSE
12	Table 3		Monitored Phyto-attenuation does not seem feasible for most of the plumes based on the limited depth effectiveness. Although groundwater is relatively shallow, TCE impacts extend much greater than 10 feet bgs in several areas. Please provide more details needed on why this alternative was retained.	Agreed. We reject engineered phytoremediation in the screening of technologies but retain phytoremediation where it occurs due to existing trees that will remain in areas not developed. In this application, phytoremediation is considered a compliment to or component of MNA in areas not likely to be developed due to inaccessibility or wetlands (e.g., the distal (east) end of the Admin Area plume, distal (southern) end of Area 34 plume, Area 5). Per the December 14, 2022 meeting discussion, we will remove monitored phyto-attenuation from the screening table as a separate technology and will describe it as a component of MNA.
13	Table 3		Please address the additional limitations for biodegradation alternative, such as access limitations beneath buildings or forested areas, and potential issues in areas with deeper groundwater contamination.	Agreed. We will provide additional explanation. There are options that will allow application of bioremediation beneath buildings or in forested areas. Installation of injection wells and piping may be coordinated with building construction or horizontal injection wells may be utilized beneath buildings. Paths for drilling and injection equipment will be required in forested areas. Injection well cost will increase with the depth of contamination and overall bioremediation cost increases with greater vertical thickness (i.e., aquifer volume) requiring treatment.

REVIEW COMMENTS AND RESPONSES

Agency Review Draft

Draft Focused Feasibility Study Work Plan, Former Boeing Tulalip Test Site

Reviewers: EPA/Jacobs

Review Date: November 2022

ITEM	PAGE	SECT/PARA	COMMENT	RESPONSE
14	Table 3		Most efficient pump and treat designs that include injection of treated water from an ex-situ treatment process, include extraction and injection well(s) pairing to promote optimized flow paths through the aquifer to breakup stagnation zones, aggressively flush high concentration areas, and promote back-diffusion. In the FA description of the alternative that includes this technology, please include a model supporting pumping/injection strategy/plan that shows the intention to promote re-circulation.	Agreed. For the DGR alternative, we will have a conceptual design that incorporates paired pumping/injection strategy. We will support the conceptual design with a simple batch-flush model for evaluation of restoration time frames.
15	Figure 2/Page 2	Third Bullet	Based on the July 2022 data available, Area 8 appears to still have several VC exceedances above 2 ug/L. The figure seems deceptive based on the low-density of sampling there. Please update the text with the most recent data.	We used January 2022 results because more wells are sampled during the annual January event than the semiannual July event, resulting in a better synoptic event. It's correct that VC at TGW132 was below the PRG in January 2022 (1.5 ug/L), then above the PRG in July 2022 (2.94). We will revise the figures and text to reflect data through July 2022; VC exceeded the PRG at two wells in July 2022.
16	Table 5		Each individual MNA technology (MNA/phyto-attenuation) should be listed out separately for the alternative name since MNA is a technology type and process option. Vapor barrier is noted as an institutional/engineering control but is included in some of the alternatives without IC/EC as part of the alternative and/or is listed as part of MNA.	Agreed. We will revise the alternative names to be more descriptive/inclusive. For bioremediation and DGR alternatives, we will show institutional and engineering controls as required until treatment achieves RAOs.

QCV Comments on Technical Memorandum- Oct 18, 2022 Draft Focused Feasibility Study Work Plan-

Submitted by Allison Warner, Quil Ceda Village 11/10/2022

The Tribes gave verbal approval of the revised FS work plan during the project meeting on February 15, 2023. The FS work plan was revised to incorporate these comments and responses.

Item	Page/Para	Section	Excerpt commented on	Comment	Boeing Response
1	1	Introduction	RAOs	Please provide a list of acronyms- or use full word, with acronym to be used for it in parenthesis as is standard for first time used. I looked at prior docs to find this but couldn't- found later in document.	RAOs (Remedial Action Objectives) are defined in the first sentence of the document. We will add a full list of acronyms in this document.
2	2/2	Areas of Concern	AOC plumes bullets	Confusing summary of various areas. Area 1 mentions "TCE coupled with low levels of cDCE" (are these TCE detections above PRG, are cDCE below?) whereas Area 8 and Area 34 state that "exposure risk was found to be acceptable in the BRA." (not what it said in BRA Apr 12 draft p xvi) Summary Table of Risk drivers in the BRA Executive summary shows hazard index (HI) above 1 for Area 34 and other areas as well. Would suggest removing these two comments or including similar for each area, or better: adding a summary paragraph addressing risk as opposed to status since these	Agreed. We will clarify how cVOCs compare to proposed PRGs in each area. Will clarify that BRA showed no acceptable risk for Area 34 at the end of the treatability test and for Area 8 despite VC in both areas above the PRG. Despite no unacceptable risk, these two areas are included in the FS due to the PRG exceedances.

				<p>bullets primarily describe the status of each area with respect to TCE etc, and perhaps adding the table to document these statements. Also, a concentration of 4.87 ug/L is over 2 times the PRG. No explanation why this ended up acceptable risk for construction workers if work is conducted in vicinity of this well. Looking at Fig 1 and 2, it is clear that Area 8 plume has been reduced significantly. It may be helpful as part of the summary to mention the relative size reductions of the plumes and refer to the figure. From the text as it is, it is unclear why a cleanup is being proposed at all given everything seems to be at "acceptable risk." Would suggest perhaps a more thorough summary to guide the reader from the BRA to this document. The next section moves from this summary saying there is "no risk", to RAOs to prevent ingestions or direct contact. This document should clarify why there is a cleanup proposed. The summary on p. xvi of the BRA with respect to cVOCs in groundwater seems more appropriate description of status and reason for this FS, also</p>	<p>Will add more information to the summary and point the reader to more detailed information in the RI Summary Report, Data Gaps Report, and the BRA.</p> <p>Will clarify that the FS will address (and PRGs apply to) the four plumes with unacceptable risk (Area 1, Area 5, Area 41, Admin) and to the two areas without unacceptable risk but where groundwater concentrations still exceed the PRGs (Area 8 and Area 34).</p>
--	--	--	--	--	---

				the section on vapor intrusion, making it clear the lack of risk is based on the assumption that mitigation measures will be in place. Otherwise its not very fact-based to just say there is no risk and these statements in this bulleted section seem to be contradictory to proceeding with FS.	
3	2	Remedial Action Objectives		Agree with stated bullets, except remove in RAO-2 clause: "by commercial workers." Should just state "for protection of potential future use as drinking water." Commercial workers may not be only ones drinking water in the future at this site. The public could use drinking fountains or at the food vendors at the site they could use tap water.	As presented in the BRA, commercial workers represent the receptor most affected by potential use of impacted groundwater as drinking water and are, therefore, the basis for risk calculations. Any exposure to groundwater as drinking water by the general public would be at a much lower frequency and duration. Therefore, levels protective of commercial workers are also protective of the general public.
4	3/para 2	Groundwater Preliminary Remediation Goals	"The MCLs are lower than COC concentrations calculated for 10 ⁵ cancer risk..."	This sentence is confusing. Do you mean the MCLs used as the screening levels were lower than what was calculated based on levels at the site because the site was lower, or what was used in the analysis of cancer risk was a	Agreed. Will revise to clarify that the MCLs are selected as the PRGs because they are lower than calculated groundwater concentrations protective of cancer risk (10 ⁻⁵) and non-cancer risk (target hazard quotient of 1)

				different target than the MCL. Maybe it should say' "COC concentrations <u>used</u> for 10 ⁵ cancer risk calculations" I think the sentence "the lowest values are used as proposed PRGs" may add to the confusion. I am thinking both sentences could be deleted or somehow re-written for clarity.	for the various potential future risk pathways and are in agreement with other ARARs.
5	3	Indoor Air	"Vapor intrusion to indoor air is not a current risk at the Site,...."	This seems a pretty broad brush (extending to the entire Site) for results from one building that has a very thick cement building pad. And contradicts that the BRA stated that vapor intrusion was incomplete because it was assumed vapor barriers would be used. One could logically conclude this means you don't need to do any vapor intrusion mitigation or evaluation then. Also, the text should make clear the Action levels are based on EPA recommendations with a reference to the document cited for Table 2. Otherwise it is unclear why these levels are chosen.	<p>The rest of that paragraph provides clarification for this statement that vapor intrusion is not a CURRENT risk at the site.</p> <ul style="list-style-type: none"> • not at Building 16-368, based on indoor air results. • not at occupied buildings over the Area 41 plume because TCE occurs deeper in the water column and is not present at the water table. • not elsewhere at the site because there are no current occupied buildings over plumes. <p>The next paragraph describes how potential vapor intrusion will be evaluated and mitigated for FUTURE buildings that may be built over the groundwater plumes.</p>

					Agreed. Will reference in the text that the VI action levels and indoor air PRGs are calculated using the EPA VISL calculator.
6	4/para 1	Indoor Air	Table 2	Shouldn't a depth also be included in this table? The prior paragraph on p. 3 states for Area 41 vapor intrusion isn't a consideration due to the depth of the plume. I didn't check but don't Area 41 TCE levels exceed the action levels given in Table 2?	Agreed. Will add a footnote to Table 2, Groundwater Protective of Indoor Air (1). (1) Applies to groundwater at the shallowest groundwater interval (water table).
7	Table 3	Screening Technologies	Physical/hydraulic containment	Given that there are timeline concerns for redevelopment of Area 41 vs potential treatment timeline and timeline for attenuation, I am wondering if this might be an option to retain. Also, there appears to be a sentence fragment on Screening comments column: "Also does not treat or remove mass." Perhaps Area 41 is too deep for this solution?	Containment refers to technologies that prevent the lateral spread of groundwater contaminants. Containment does not apply to Area 41 (is not necessary) because the plume has spread downgradient to the WFQC and can spread no further due to capture by the creek; cVOCs are not detected in the creek so there are no creek impacts to address through containment. However, a vapor barrier is a retained technology for preventing vapor intrusion into future buildings. This technology

					<p>may have application in Area 41 or other areas where new buildings may be constructed over plumes.</p> <p>“Also does not treat or remove mass.” is not a fragment and is a statement regarding physical barriers.</p>
8	5/para 1	Table 4	Restrictive...controls	<p>I am not sure this option works for Tulalip Tribes or QCV . It could be retained as an alternative but not likely acceptable or compatible with planned uses, depending on what is involved.</p>	<p>Further discussion with the Tribes is needed as to what institutional controls would look like. Likely controls would be temporary until groundwater treatment is completed. Institutional controls could include QCV plans or policies such as:</p> <ul style="list-style-type: none"> • no deep excavation work in plume areas except by trained crews with appropriate health and safety precautions. • no drilling of water supply wells in plume areas until groundwater treatment is completed.

					The Tribes restriction on further water well drilling on the reservation, as described in the Tribes Comprehensive Land Use Plan, constitutes an institutional control.